A SYSTEMS APPROACH FOR COPING WITH
CATTLE PRICE VARIATIONS

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PREFACE

A model for analyzing dynamic cow-calf herd management strategies was developed. The cow-calf- stocker simulation model incorporates a stocker growth model, a cow herd breeding and replacement model, a forage utilization model, a variable and fixed cost model, and dynamic prices. The model has the capacity to sell stockers (feeder calves) at any age or weight, to cull/replace cows at any age, and to have multiple calving periods. The model incorporates a cyclical grassfed stocker herd into a cyclical cow-calf herd in developing herd management strategies.

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TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

Table		Page

Table | Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION TO THE STUDY

Cow-calf producers face unstable prices--specifically cyclical and seasonal output prices. For years, economists have observed a repetitive cattle cycle that varies from nine to 20 years. Seasonal price patterns also exist for feeder calves. Prices typically drop during the fall when weaned cattle flood the market and rise in the spring when scarcities occur. In addition to these output price patterns, producers face rising and variable input costs. These price patterns make cow-calf producer profits highly volatile. Thus, an ability to effectively understand and deal with the cattle price cycle is imperative.

It is difficult for cow-calf producers to cope with the cattle price cycle. Cow-calf firms are characterized by a high proportion of fixed costs which cannot be avoided by adjusting the firm's level of activity. In addition, firm production levels can only be adjusted slowly due to the biological nature of beef production. With high fixed costs, variable profits, and an inability to adjust production rapidly, cow-calf producers cannot afford to make very many mistakes with the price cycle. Ideally, a producer would "gear up" for the "boom" phase of the cattle price cycle, and have his largest and most productive herd going into the peak of the price cycle. He would then allow the herd to decline in size in the downphase. Strategies to achieve this ideal may involve culling and replacement to vary the breeding herd size as well as strategies that vary the firm's enterprise mix by holding more or less stocker cattle relative to brood cow numbers. While these types of strategies would be designed to cope with the long-run problem of price cycles, they must also be compatible with short-run strategies that take advantage of seasonal prices and pasture productivity by seasons of the year.

This research focuses upon the development of strategies that Oklahoma native grass ranchers can use to deal with "known" cyclical and seasonal output price variability. Only typical price variation patterns are analyzed. The strategies developed are not designed to cope with abnormal conditions or special situations. As such they are standard guidelines from which adjustments for special situations can be based.

An assumed typical Oklahoma ranch type is used as the model. The ranch is modeled to have a fixed land base and be primarily an owner/operator ranch with a minimum of hired labor. An ability to produce both calves and stocker cattle is assumed. For convenience, the base size of the ranch is a 100 head brood cow herd. Technology used and production efficiency levels are assumed to be approximately that of current progressive ranchers. Average conditions were assumed.

Objectives

The objective of this research is to develop a pragmatic herd management strategy for Oklahoma cow-calf producers to use in coping with known cattle price variations. Specific objectives are to:

1. Determine if it is profitable to expand and contract the brood cow herd at certain points in the cattle price cycle, and if so, when and how much;

2. Determine if it is profitable to change the brood cow/stocker cattle enterprise composition at certain points in the price cycle, and if so, when and how much; and

3. Determine the optimal month for selling stocker cattle during the year and whether this month changes over the cycle or as a part of a long-run strategy.

Procedural Overview

A systems analysis and modeling approach leading to the development of a pragmatic herd management strategy is used in this research. The analysis begins with a description of the volatile price situation faced by cow-calf producers. Following this, a simulation model is built to describe the physical dynamics of various culling, replacement and stocker cattle marketing decisions and their impacts upon herd composition and pasture utilization. This model will then used to evaluate the potential effectiveness of various strategies considered feasible for producers. Specific steps and methodology in the procedure include the following:

1. Typical dynamic price patterns and relationships are estimated using econometric models of monthly cattle prices (1958-1977). Trend, cycle, and seasonality variables as well as

grade, sex and weight variables are used to model price patterns and relationships over time.

2. The physical dynamics of the cattle growth and forage requirements are modeled. Information for this modeling are drawn from economic production research, agronomy research, and animal science research.

Basic attributes to be modeled include: a) calving weight and weaning success by cow age; b) cull cow death rates and slaughter weights by age; c) stocker cattle growth rates by sex, weaning weight and season of the year; d) forage/feed requirements by season, cow age, stocker weight, and stocker sex; and e) pasture forage availability by month.

3. General accounting procedures are used in conjunction with the physical simulation model to simulate income and costs for the ranch. Net returns estimates by age of brood cow, stocker weaning weight, sex, and sales date are kept. Cost calculations are internally adjusted to reflect diseconomies of size due to supplemental feed requirements and other rising variable costs per unit of production.

4. The above information and model are used in analyzing and developing pragmatic herdsize and composition strategies for cow-calf-stocker operations given typical cyclical and seasonal price patterns or other "perfect knowledge" scenarios of future prices.

CHAPTER II

LITERATURE REVIEW

In developing the cow-calf-stocker model, literature in four major areas was reviewed including price analysis, capital investment theory, animal science production and performance studies, and economic modeling methodology. The remainder of this chapter summarizes the information gleaned in each of these four areas.

Price Analysis Literature

Price analysis was the first area of literature reviewed. A realistic description of cyclical and seasonal price patterns for beef cattle is needed to derive meaningful dynamic management strategies. Prices of feeder and stocker cattle and cull cows are key prices for herd management decisions. In addition, trends and variations in production costs are critical to describing the firm's projected profit and loss situation.

The cyclical and seasonal prices of feeders, stockers and cull cows are important, but relative prices over time are perhaps more important. For example, the price ratio of a 400 pound heifer versus her current slaughter market value is critical in evaluating the replacement value of a heifer. A proper relationship between steer and heifer price ratios and any systematic dynamic patterns in the steer-heifer price ratio are required to properly evaluate the product of the ranch since the sex composition of the firm's feeder calf/stocker sales will vary with culling and replacement decisions.

The price analysis literature review focused on describing price patterns and relations instead of forecasting prices. Literature defining cyclical price patterns and determining feeder-stocker prices over various weight ranges was especially sought.

Cattle cycle phenomena has been observed since the late 1800's. Breimyer (1955) summarized the literature and divided it into two schools of thought. The first school contended that the cattle cycle is self-generating, and the second school contended that the cattle cycle is caused by outside influences. Breimyer supported the school of thought that the cattle cycle is self-generating, but is influenced by outside factors. Breimyer estimated the relationship of cattle inventory numbers, slaughter numbers, price ratios, and price levels. He found that changes in cattle numbers on farms were augmented by holding not only steers and heifers, but all classes of cattle for a longer or shorter period of time. In general, Breimyer suggested that the cattle inventory cycle varies between 10 and 16 years, with the amplitude of the cycle varying between 23 and 35 percent.

Breimyer's work supports the work of Foote (1953). Foote estimated, in sequence, a four equation model relating the price of corn, the number of grain consuming animal units fed, the price of livestock, and the production of livestock. The four equation model was used to predict cattle cycles. Foote concluded that there was an inner mechanism which seemed to generate a series of prices and quantities, and that the model would always have more cyclical fluctations than are actually observed.

Following Foote, a number of economentric models were developed describing the cattle cycle. Nerlove (1958) incorporated distributed lags into a model that predicted the cattle cycle. Compared to models without distributed lags, the dynamic distributed lag model explained the data better, and the coefficients were more reasonable in size and magnitude than traditional static models. Walters (1965), using numbers of cattle rather than prices, divided cattle into four categories: (1) cows and heifers two years and over; (2) heifers and steers one to two years; (3) calves; and (4) bulls one and over. These cattle numbers were used to predict the cattle cycle. Walter's model worked well, but there were discrepancies between estimates from the model and estimates using survey data.

Langemeier and Thompson (1967) developed the most thorough model published during the 60's. They used a 12-equation model to predict the cattle cycle. The model allowed for simultaneity between long run supply and demand. Their major contribution was inclusion of the simultaneous prediction of cattle supply and demand.

In 1970, Crom developed a recursive cobweb model for beef and pork. This quarterly model had components for fed beef, nonfed beef, and pork. Then, in 1972 Crom developed a behavioral model for the cattle cycle for use in forecasting beef prices. The forecasting model utilized operating rules to change parameters when specified conditions arise, thus incorporating "dummy variables" into the price analysis.

Franzmann's (1971) work reflects a different approach to describing the cattle cycle. He used monthly data in identifying a stable cattle cycle that is approximately 10 years in length. Following the Fourier Theorem of periodic variation, Franzmann identified cyclical, seasonal, and trendular variability, and found that cyclical variability was dominant. The stability of the cycle, its amplitude, phase relationships, and turning points added reliability for the model to be used in forecasting cattle prices. Even though the precise estimates may not always be obtained, the model appeared reliable in predicting price patterns.

Hummer and Campbell (1972) looked at differences in feeder cattle prices by weight groups. They considered the affects of season, grade, and sex upon price differences between various weights of animals. Prices generally moved inversely to cattle marketings, dropping to a low of 96 percent of the annual average in October and a peak of 103 percent of the annual average in June. Slaughter cow prices were found to be generally highest in April and lowest in November with a much greater seasonal variation than slaughter steer and heifer prices. Prices for stocker-feeder cattle peaked between April and June and were lowest in October. Ssekitooleko and Kuehn (1979) also identified sex, season, grade, and year of the sale as major factors in feeder cattle prices. Keith and Purcell (1976) found a seasonal and somewhat cyclical slaughter pattern during the 1970's. After fitting a quarterly per capita beef production model, they observed a marked change in the producer's decision-making patterns during the upswing of the cycle and another definite change during the downswing of the cycle. Producers tended to expand herds during the upphase of the cycle and sell heifers in the downphase, thus liquidating the herd.

Following Hummer and Campbell's analysis of price relationships, King (1979) identified choice feeder steer price as the basis for his analysis. Using trigonometric functions similar to those identified by Franzmann, King used annual data to predict trendular and cyclical price relationships for feeder cattle. Rather than independently estimating feeder steer and heifer prices, King found it more efficient to first estimate feeder steer prices and then estimate the trend, cyclical and seasonal variation of the "spread" between feeder steer and heifer prices. The estimated spread was then used in conjunction with the feeder steer price estimate to determine heifer prices.

To summarize, the literature indicated a trendular increase in cattle numbers and prices. The theory that the cycle is self generating and is of nine to 20 years long dominates the literature (Breimyer). Cyclical, trendular, and seasonal variability were identified as key measures of price patterns. Age, weight, grade and sex of the animal were also identified as key elements in cattle price analysis.

Franzmann's work was particularly relevant to the needs of this thesis research. Based on this literature review the methodology selected for use here is described as follows. Monthly time series data were chosen to estimate price variations over time. Trigonometric functions of the type used by Franzmann were used to describe cyclical patterns. Monthly dummies were incorporated to indicate seasonal price variation. Separate price relationships were designated to reflect the relationship between prices for animals of different weights, grades, and sexes. The steer-heifer price spread relationship was identified as the appropriate method of determining heifer prices. Following King's procedure, steer prices were projected first using time series equations. Heifer prices were then determined from steer prices. The heifer price equation used contains cyclical, monthly, trendular, weight, grade, and steer price variables. Cull cow prices were estimated independently of the steer price by utilizing a separate trigonometric function.

Capital Investment Theory

Capital investment theory was the second area of literature considered. Cow herd culling and replacement decisions are basically asset replacement decisions. Productivity criteria such as age, breeding probabilities, and calf weaning weights are perceived to affect culling or replacement decisions for different aged cows. Brood cows are assets that generate revenue flows over their entire lifetime. Hence, estimates of the future value of revenue flows expected over their productive life are needed to properly evaluate culling or replacement decisions. Also, herd size, productivity, and composition in relation to the cattle cycle are expected to enter into dynamic management strategies.

Faris's (1960) article was chosen as a starting point in the review of asset replacement research. Faris looked at optimal replacement patterns for stands of trees in a commercial forest. Expanding his study, Faris looked at assets that had long production periods with a stream or flow of revenue throughout the life of the asset. He proposed that the optimal replacement time is when the marginal net revenue (the annual net revenue) from the present enterprise equals the highest amortized present value of the anticipated net revenue from the replacement enterprise. Specifically, when evaluating cling peach trees, Faris identified an equation for expressing the net revenue in any year:

$$(1)\quad NR_n = Y_n - A_{n-1}i - b_n - c_n$$

where:

NR_n = net revenue in year n

Y_n = gross revenue in year n

$A_{n-1}i$ = interest on the unpaid balance of the establishing cost at the beginning of the year (or end of previous year, n-1)

b_n = annual cost in year n

c_n = planting cost in year n

n = the duration of a production period

and an equation to determine the amortized present value of net revenue in year n:

$$(2)\quad A_{NR_n} = \sum_{k=0}^{n} \frac{Y_k - a_{k-1}i - b_k - c_k}{(1+r)^k} \quad \frac{r(1+r)^n}{(1+r)^n - 1}$$

where:

A_{NR_n} = amortized present value of net revenue in year n

r = discount rate for time preference

i = interest rate for establishing an annual cost

Y_k = gross revenue in year k

$a_{k-1}i$ = interest on the unpaid balance of the establishing cost at the beginning of the year (or previous year, k-1)

a_{-1} = 0.0

b_k = annual cost in year k

c_k = planting costs in year k

Chisholm (1966) clarified Faris' research by identifying the net present value criterion as the appropriate solution to the asset replacement problem. Chisholm proposed to select the production period which maximizes the net present value for a perpetual sequence of production periods rather than the single production period having the maximum net present value.

Essentially, Chisholm identified the net present value criterion as:

$$(3)\quad PNV^* = \frac{P_1}{(1+i)^n} + \frac{P_2}{(1+i)^{2n}} + \ldots + \frac{P_t}{(1+i)^{tn}}$$

$$\text{or } PNV^* = PNV + \frac{PNV}{(1+i)^n-1}$$

where:

PNV = net present value of revenue in year n

PNV* = maximum net present value of revenue in year n

P_t = net present value of revenue in year t

i = interest rate for an annual costs

t = the number of production periods

or when $P_1 = P_2 = P_3 = \ldots = P_t$:

$$(4)\quad A^* = \frac{Pi}{(1+i)^n-1}$$

where:

A* = the amortization value

The net present value criterion for an optimal could then be interpreted as:

$$(5)\quad V_{n+1} - V_n - c_n - iV_n \leq A^* \leq V_n - V_{n-1} - c_{n-1} - i\, V_{n-1}$$

where:

V_n = total revenue from the sale of the timber at age n,

i = interest rate for an annual cost

c_n = annual running cost at age n

A^* = amortization value

$\Delta V - iV_n - c_n$ = marginal net revenue

Perrin (1972) investigated asset replacement under certainty. He compared gains obtained by keeping the current asset for another time interval with the opportunity gains that could be realized from a replacement asset during the same period. Perrin (as further defined by Trapp, 1980) identified the following equation for replacement strategies:

$$(6)\quad R_s(t) + \Delta M_s(t) < \frac{r}{1-(1+r)^{-t}} \left[\sum_{t=0}^{c} (1+r)^{-t} R_{s+t}(t) - M_2(0) + M_{s+c}(0) \right]$$

where:

$R_s(t)$ = expected net revenue generated over year t by a cow s years of age

$\Delta M_s(t)$ = market value of a s year old cow in year t

$M_s(t)$ = $M_{s+1}(t+1) - M_s(t)$

r = discount rate

c = alternative number of additional years to hold a cow before culling her

s = cow's current age in years

t = time counter where t=0 is the current year

The optimal replacement age could be determined by maximizing the present value of the entire future stream of residual earnings from the productive process associated with the asset.

Specific applications of replacement theory to the culling and replacement of herd breeding animals seems to have begun with Burt (1965). He considered optimal replacement under risk. After separating interest into components for risk and time preference, Burt looked at planned and random replacement due to death or calving failure. After considering age and productivity of the asset, he determined that the best replacement criterion is the expected value of discounted net revenues from the asset.

Rogers (1971, 1972) applied the net present value criterion to beef cattle by comparing the amortized returns from a single replacement heifer with the returns of a single cow in the herd. The parameters he identified that are influenced by the age of the cow and therefore those that influence replacement age are: (1) percentage of the calf crop weaned, (2) calf weaning weights, (3) death loss of the cow, and (4) sale value of the cow. Rogers used the replacement criterion of: when the replacement animal's amortized returns exceed the returns from a cow currently in the herd, the cow should be culled and replaced with a heifer. Rogers based the net present value of a cow on the formula:

$$(7)\quad PV_n = \frac{Y_n}{(1+i)^n}$$

where:

PV_n = net present value of income from the brood cow in year n

Y_n = income received from the brood cow in year n

i = rate of interest

n = year of age of cow.

In evaluating brood cows Rogers uses the amortized net present value of a brood cow as calculated by the equation below:

$$(8)\ A = \sum_{1}^{n} PV \frac{i(1+i)^n}{(1+i)^n - 1}$$

He also found that net return calculations were complicated by the declining salvage value of cows as they advance in age.

Ladd and Gibson (1978) suggested that the level of genetic technology and its rate of progress are directly affected by culling and replacement strategies. They contended that these considerations must be endogeneous to the cattlemen's management decisions. Following their suggestion, Melton (1980) studied beef cow culling and replacement decisions under genetic progress. He found that cows should be replaced at a younger age and more often when genetic progress is possible through replacements.

Further advances in existing beef culling and replacement criteria were made when asset replacement theory was combined with cyclical price considerations and adaptive strategies were developed. Bentley, Waters, and Shumway (1976) looked at optimal beef cow replacement in the presence of stochastic elements. After considering a brood cow's productivity, they found that culling and replacement strategies were sensitive to calving success of different aged cows and cull cow prices by age, but were insensitive to feed costs and feeder cattle prices. Bentley and Shumway (1981) looked at cow culling and replacement over a 10-year planning horizon with a cyclical price pattern within this period. They observed heavy cow culling in the downphase of the cyclical price model. However, they did not observe any cyclical patterns in heifer replacements or herd size.

King (1979) looked at cow culling and replacement strategies with varying herd size over a three-cycle planning horizon. Noting that culling and replacement decisions should be made separately, he allowed the herd to expand and contract. This allowed the herd to "gear up" and have the most productive cows in the herd during the peak of the cattle price cycle. The herd then declined in productivity and size going into the downphase of the cycle. King indicated that given cyclical feeder cattle prices, the optimal cow herd size varied cyclically, and that the cow herd size should "peak" and "bottom" three years ahead of the feeder cattle price cycle. Optimal culling and replacement rates were found to be two to three times faster during the up phase of the cattle price cycle than in the downphase. Following Roger's equation, King indicated that replacement decisions with variable herd size should be:

Culling Rule: A cow of age s should be culled when:

(9) $NPV^*_s - M_s(t) = 0$, and

Replacement Rule: A heifer should be added to the herd when:

(10) $NPV_2^* - M_2(t) = 0$

where:

NPV_s = net present value of a cow of age s

$M_s(t)$ = market value of a cow of age s in time period t

The net present value of a cow of age s was determined as:

$$(11)\quad NPV_s = \frac{Y_s}{(1+i)^n}$$

where:

Y_s = net income in year s.

In summary, capital investment theory as applied to beef cattle concentrated in identifying the optimal brood cow replacement age. The capital replacement theories developed by Faris and Perrin were modified by Bentley and Shumway to reflect the probabilistic nature of calving and brood cow deaths. Following the work of Bentley and Shumway the literature then reports the evolution of research efforts toward the development of culling and replacement strategies for variable herd size.

Based on the literature reviewed, replacement strategies capable of resulting in variable herd sizes will be used in this research. Thus replacement decisions will follow the theory developed by King, which results in the following two basic rules for culling and replacement.

Culling Rule: A cow of age s should be culled when:

(12) $NPV_s^* - M_s(t)=0$, and

Replacement Rule: A heifer should be added to the herd when:

(13) $NPV_2^* - M_2(t)=0$

The net present value equations were calculated as:

$$NPV_s^* = \sum_{t=0}^{c} (1+r)^{-t}(R_w) + (R_c)-L$$

where:

NPV_s* = the maximum value of the net present value of cows of age s (NPV_s) as c is allowed to vary from zero to 15 years

r = discount rate

c = culling age of cow

R_w = gross revenue from weaned calves

R_c = salvage value of the cow of age c

L = the long run average total cost

Asset replacement theory for cow culling and replacement can also be extended and applied to stocker decisions. Following the above criterion:

Stocker Rule:

(14) A stocker should be sold when the value added by a weight gain is less than the cost of obtaining the weight gain.

$$M_t - C_t - M_{(t-1)} = 0.0$$

where:

M_t = market value of the stocker at time t

C_t = cost of weight gain for period (time) t

Thus in developing capital investment theory, criteria for evaluating cows, replacements, and stockers were developed. Although the above criteria were not explicitly calculated and used in all cases considered in this research they were the guiding concept used in developing the pragmatic strategies tested.

Biological Performance and Production

Production and performance data are important in developing a beef ranch production-marketing model. Growth rates, seasonal weather patterns, and forage availability are expected to influence cattle productivity and net farm receipts. Expenses for feed and labor requirements that vary by season and herd size are expected to influence the producers decision to hold stockers.

Fusselman and Walker (1983) developed cost and production patterns for a grassfed cow herd. They analyzed interdisciplinary research that concerned forage conditions, feed rations, weather conditions, calving patterns, cow age, replacement characteristics, and growth rates. They combined these research efforts into an economic production model for a grassfed cow herd in Oklahoma. Their model will generate seasonal cow productivity patterns (i.e. cow weights, calf weights) and cost over a one-year period given specifications of forage types and quality, the desired supplemental feed ration, the breed type of the herd, the age of the cows, and the calving season. The model automatically supplements grain or hay when forage is lacking and calculates the resulting productivity, costs, and cow value.

King (1979) also integrated multidisciplinary research in constructing his varying cow herd size culling and replacement herd management model. He identified average steer and heifer weaning weights, average birth rates, average death rates, and the average cow weights based upon the age of the brood cow. King's research indicated that the optimal composition of the cow herd in terms of both the numbers and ages of cows as well as their associated productivity is influenced by the cattle price cycle.

When faced with the problem of integrating stockers into a cow-calf herd model, seasonality in growth, costs, and value must be considered. Brorson (1981) developed seasonal cost and production patterns for a grassfed stocker operation. He analyzed interdisciplinary research concerning forage conditions, feed rations, growth patterns, and weather conditions and developed an economic growth model for grassfed stockers in Oklahoma. Brorson's model will generate seasonal growth rates and costs over the life of the grassfed stocker once forage types, the desired supplemental feed ration, the breed type of stocker, and the season of the year are identified. The model supplements grain or hay when forage is lacking and calculates the stockers growth rate, costs, and value over a one year horizon.

Stokes (1980) integrated stockers into a cow-calf operation with a constant cow herd. Options with higher returns had stocker sales concentrated around high seasonal price relationships. Stokes found that differences in monthly pricers were greater than the increased production costs of holding the stockers for sale during higher price months.

Oklahoma State University budgets further define the physical attributes of the cow-calf-stocker ranch. The budgets identify costs of labor, equipment and machinery, land and improvements, and interest rates associated with managing herds at different locations in Oklahoma.

To date no research has been reported in the literature which integrates cow-calf and stocker physical attribute models to give a comprehensive description of the nature of various cow-calf-stocker enterprise mixes. The information to do so appears to be available from Brorson, Fusselman and King's research. However, the distinctly different time frames of the two enterprises require careful dynamic interfacing.

Modeling Methodology

As the conceptual theory of replacement was developed and reported, so to were the modeling procedures to utilize this theory in analyzing cow culling and replacement decisions. Rogers (1972) utilized linear programming in his research effort. He assumed constant feed availability and feed price and omitted credit for the sale of cull cows. He recognized that linear programming assumes future prices are known with certainty so only fixed price changes were considered. A constraint of constant herd size was also placed on the model. Subject to these constraints, Rogers found the optimal culling age to be 10 years. Bentley, et al. (1976, 1981) recognized linear programming's limitation of a single valued product and a single input price. He then incorporated cyclical price patterns and stochastic elements into cattle replacement and strategy analysis. Bentley found the decision to be insensitive to the range of cattle and feed prices but sensitive to cow productivity by age as described by calving percentages by age. By incorporating a value for cull cows, Bentley's work lowered the optimal culling age to seven years.

King (1979) developed a simulation model which utilized cyclical prices, price relations between classes of animals, and variable herd size in determining an optimal herd strategy over a multiple cycle horizon. The dynamic model responded to the price cycle by both expanding and contracting the herd size and by changing the optimal culling age.

Stokes (1980) incorporated stockers into a simulation model that had a constant herd size and cyclical and seasonal prices. Results showed that when incorporating stockers into a cow-calf production unit, it was generally more profitable to continue ownership until the animals were ready for slaughter, rather than to sell them as stockers. Results also indicated that the average returns were higher from holding feeder calves than always selling feeder calves when the current price was used as a forecast.

The next apparent methodological step is to integrate stockers into a cow-calf herd simulation model. The strategy simulation model for this research is intended to incorporate a variable cow and stocker herd size and cyclical and monthly price variations.

Computer Modeling Languages

In selecting simulation computer languages, FORTRAN-based languages were selected because of their versatility, universal acceptance, and suitability to modeling time-varying dynamic systems. Due to the expected size of the model, microcomputer systems were not considered. Dynamic languages such as DYNAMO and GASPIV were also considered. DYNAMO is an excellent language for use in dynamic systems; however, it is not suitable for use in a mixed (discrete/continuous) system. Since this thesis research was expected to utilize both discrete and continuous time frames, DYNAMO was not suitable. However, valuable insights into the use of first, second and third-order delays were gained from DYNAMO.

The language to be used then must be capable of supporting a mixed system. GASPIV has this capability. GASPIV is a FORTRAN-based language that conducts both continuous and discrete functions within a FORTRAN main program. GASPIV, as DYNAMO, internally generates distributions over third-order delays such as cow aging, culling, and replacement decision that occur only once during the year. The problem with GASPIV is the internal workings of the language. This made it difficult to modify the language for several specific design changes needed. For example, there was an inability to "get at" or attrition a variable while it was in the delay. If the desired decision is to sell 425-450 pound steers and the steers are in a 400-500 pound growth delay process could only the 425-450 pound steers to be sold or attritioned out of the delay? Because of possible problems in accessing such internal data, GASPIV was eliminated from consideration. On the other hand, FORTRAN based delays could be built individually and be accessible to the researcher. Thus, the researcher could build in the ability to attrition or add to the delay and keep track of each individual animal in the system as desired. Therefore, FORTRAN was selected because of its adaptability.

Summary

In summary, the literature and its application to the research led to the development of:

1. Trigonometric and linear price projections that incorporate seasonal variability, weight and feed relationships, and price relationships between classes of cattle;

2. Selection of a modeling language that incorporates desired distributions into functions that are developed to fit a specified need; and

3. Development of physical parameters relative to the dynamic modeling of an integrated cow-calf-stocker ranch. Such physical parameters include pasture production of forage by month, forage and feed supplements required by cows and stockers by month, forage and feed supplement required by the ranch while varying the stocking rate and herd size, labor requirements per animal per month, labor requirements required by the ranch while varying the stocking rate and herd size, other variable costs per animal by month, fixed costs of the ranch, cow productivity by age of cow, calf weaning weights by age of cow, and stocker growth rates by sex, weight, and month.

CHAPTER III

THE MODEL

The basic model reflects a 100-head cow-calf-stocker ranch. The model's structure simulates the physical and financial results of alternative herd culling, replacement and stocker retention decisions. To achieve this, the model contains both physical and economic components. There are three major components of the animal model: a cow herd model, a stocker growth model and a replacement heifer model (Figure 3-1). The major economic components include an input cost model, an input and output price scenario model, and an accounting model which generates summaries of revenues, costs, and other economic information. Major cost components include a forage model and a labor cost model. Figure 3-2 shows a schematic diagram of the integrated cow herd and stocker growth model. The economic and forage availability models will be developed in detail later.

The major attributes of the cowherd and stocker growth model depicted in Figure 3-2 are as follows. Cows can be held in the herd from age two through 16, or upon weaning one through 15 weaned calves. Specific breeding rates (BR) and calf weaning weights (WW) are associated with each cow age. When the calves are weaned, some heifers are selected as replacement heifers. The number selected depends on the replacement strategy used. Phenotypically heavier heifers are retained as replacements, and lighter weight heifers are

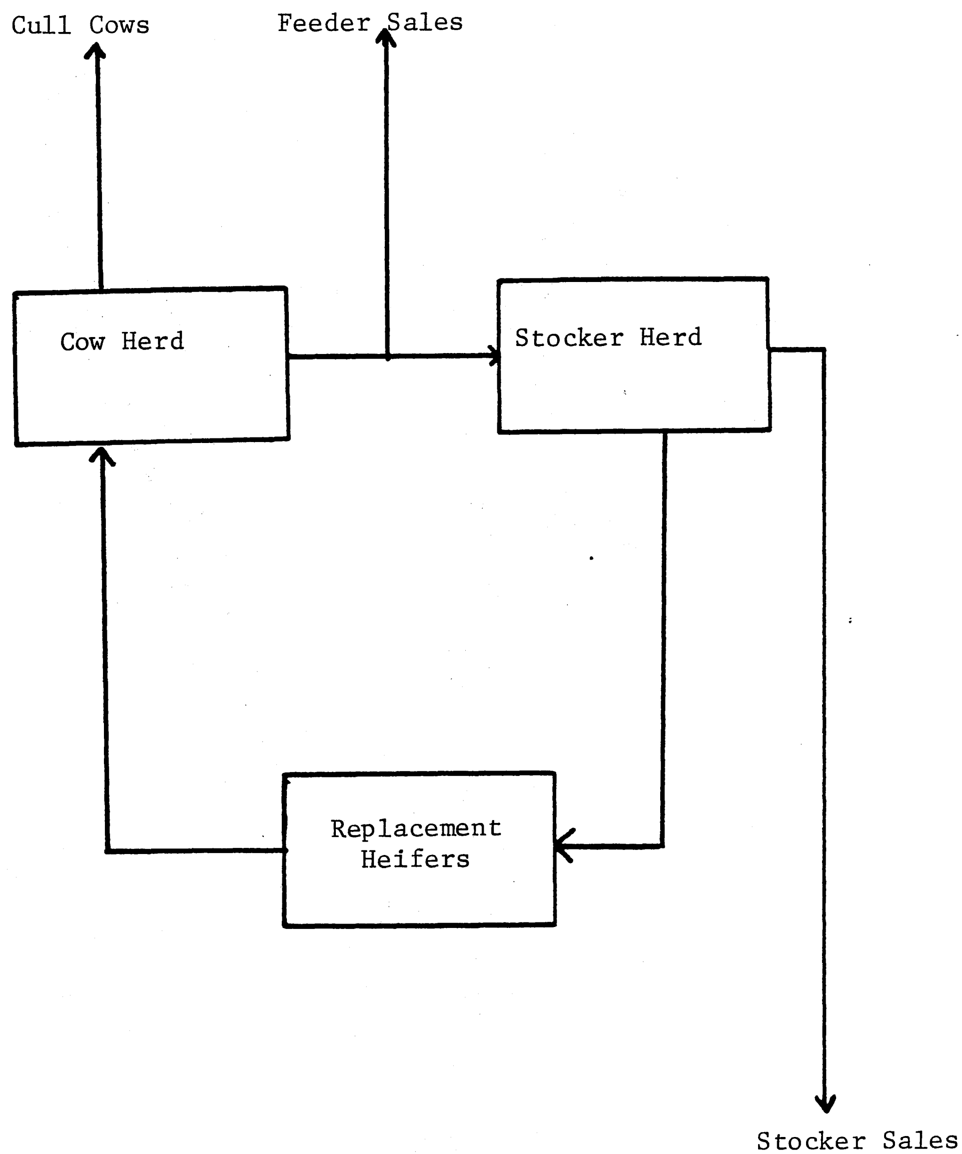


Figure 3-1. The General Animal Model

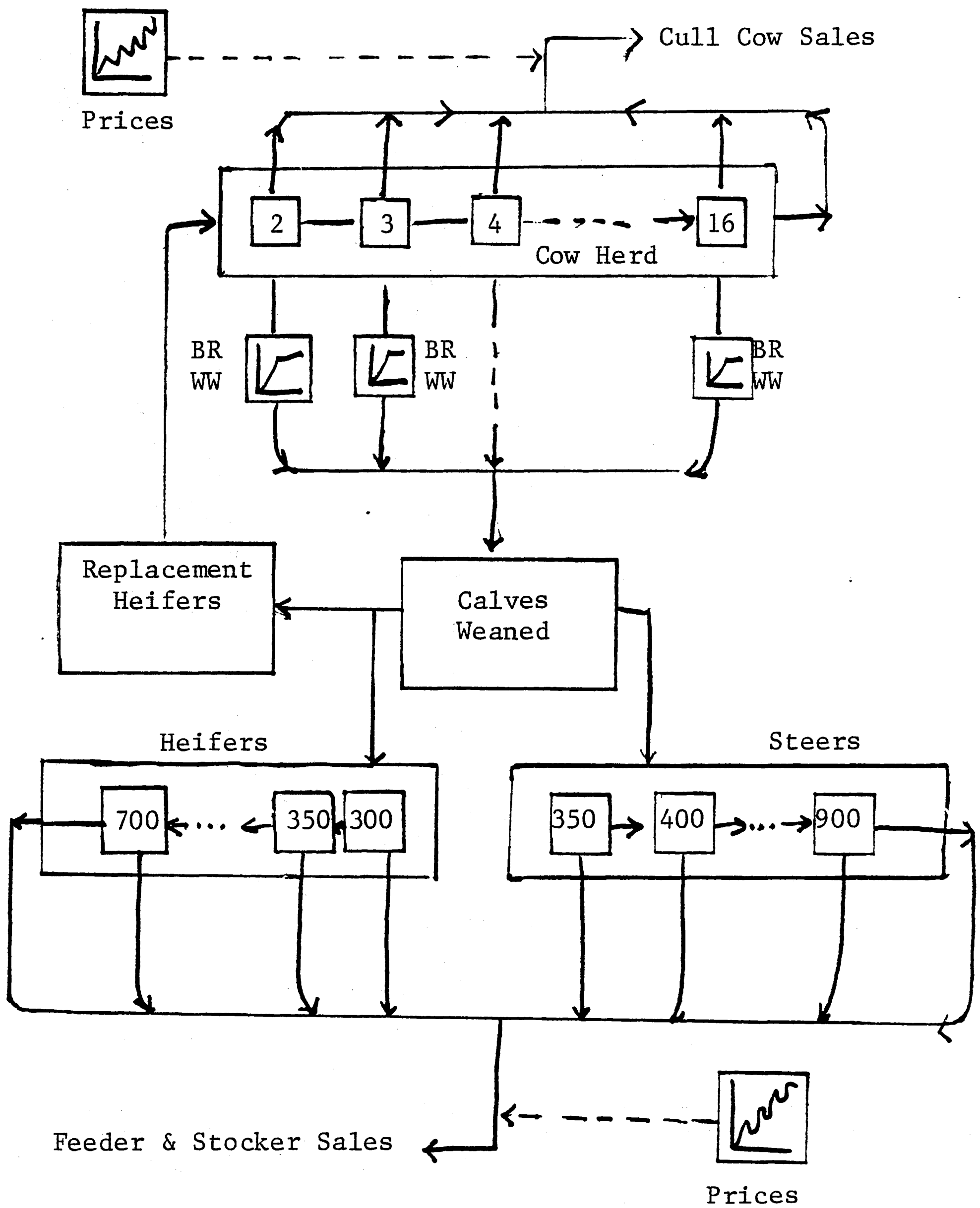


Figure 3-2. Cowherd Sector, Stocker Cattle Sector, and a Replacement Heifer Sector of the General Model

identified as stockers. Cows may be culled from the herd at any age. Two types of culling are allowed. The first is culling because the cow reaches a specified age at which she is no longer felt to be productive and the second is culling for poor performance by an individual cow. In this model any cow failing to wean a calf for the second time was culled regardless of her current age.

The grassfed stocker model identifies inventories of animals by 50-pound weight intervals and by sex and grade. The stockers can be sold at any weight between weaning weight and a terminal fat cattle weight. Prior to discussing additional specific sectors of the model, the modeling metholodgy and procedure used in programming the cow herd and stocker growth models will be presented.

General Modeling Components

Dynamics of time play an important role in the cow-calf-stocker simulation model. Gestation periods, stocker growth, and aging of cows and replacements require time. Forage availability and quality are also seasonal, thus time dependent.

In cases where a specific time period, or delay, is needed between events, such as a breeding to calving delay, or the aging of a cow by one year, a standardized discrete delay simulation subroutine is used. The delay subroutine model accepts entries into the delay process each period as "inflows." In a dynamic model such entries must be described in terms of "flow rates" or numbers per period of time. The discrete delay subroutine is capable of receiving any sequence of inflows and then generating, X periods later, the exact same sequence of outflow rates. The information contained within the delay subroutines calculations can also be used to determine the "stock" or inventory of animals in the delay process at any point in time. These properties make the discrete delay model a natural method for accounting for brood cow populations by age. Inflows into the delay are replacements per year, and outflows are culls per year. The inventory is the brood cow population.

Figure 3-3 lists the FORTRAN code of the basic Discrete Delay Model used in this research (further discussion of the properties and use of this delay model can be found in Manetsch and Park (1974). The model is referred to as the DCTDEL model for Discrete Delay. The animals in the delay are identified as "stocks" or numbers at a specific time. Thus, 100.0 percent of the flows entering DCTDEL at time T, exit DCTDEL at time T + X, where X = the desired length of the delay. The delay model can be modified to account for deaths and early culling due to performance failures. The delay program is written so that it generates the proper length of the delay regardless of the time period the model uses, i.e. quarterly, monthly, daily, etc. This is done by internally calculating N, the number of model time periods of the delay, as N=X/DT where DT is the modeling time period.

In many biological process delays the length of time required for the process to be completed is not known with certainty. Such is the case with stocker cattle growth. The amount of time required for a stocker to gain 100 pounds is not certain, but rather an expected value with a distribution. Continuous, or distributed delay models, have been developed to describe such delay processes.

```
SUBROUTINE DCTDEL  (VIN, VOUT, VINT, N)
DIMENSION VINT (N)
VOUT = VINT (1)
DO 1 I=2,N
1 VINT (I-1) = VINT (I)
VINT (N) = VIN
RETURN
END
```

where: N = the number of stages or time periods within the delay; N is calculated as (delay time length/DT)

VIN = rate into the delay

VOUT = rate out of the delay

VINT = intermediate flows with the delay

DT = time increment

Source: Manetsch and Park (1974)

Figure 3 - 3. A Coded Fortran Subroutine for Simulating Discrete Delays.

Continuous/distributed delay models are similar in concept to discrete delays, except inflows into the delay proceed through the delay in a probabilistic fashion. Within a distributed delay, percentages of the flows are progressivily moved through various stages of the delay in any one time period. Therefore the flows exit the delay in a distributed manner. In this research a distribution around each growth rate is used to allow for variability in growth associated with inferior or superior stocker performance. The continuous distributed delay was chosen to model the stocker growth and hence allows for a distribution of stocker growth rates within the weight gain delays.

To realistically describe stocker growth, several other complicating factors need to be considered. Data from the literature review indicated that allowances need to be made for monthly changes in growth rates that vary by animal weight, nutritional requirements, and forage availability. Such conditions indicated the need for a set of continuous delay models capable of adjusting the length of the delay for a given amount of growth as the stocker growth rate changes. Such models are referred to in the literature as "time varying delays." For example, 38 days are required for a 450 lb. steer to gain 50 pounds using May's average daily gain of 1.3 lb./day, while 500 days are required for the 450 lb. steer to gain 50 pounds using December's average daily gain of 0.1 lb./day. To allow for a distributed delay combined with a time-varying delay model, the time-varying-distributed delay, called VDEL, was selected to model stocker growth (Figure 3-4). Because of the need to consider weight, nutrition and seasonality of growth the stocker growth process was modeled by a series of VDEL routines. The subroutines were placed in

```
SUBROUTINE VDEL (VIN, VOUT, R, DEL, DELP, DT, K)
DIMENSION R(K)
A    = DT*K/DEL
DELD = (DEL-DELP)/(DT*K)
DELP = DEL
V    = VIN
DO 1 I = 1, K
DR   = R(I)
R(I) = DR + A* (V-DR*(1.0 + DELD))
1 V  = DR
VOUT = R(K)
RETURN
END
```

where:

VIN = rate into the delay
VOUT = rate our of the delay
DEL = present length of the delay
DELP = past length of the delay
DELD = difference between DEL-DELP that represents an adjustment for changing delay length
A = adjustment for percentages to be moved
DT = time increment
K = number of stages through which the rate must move
R = rate within each K state
DR = rate R within each K state at time
V = stage at a given time

Source: Manetsch and Park (1974).

Figure 3 - 4. A Coded FORTRAN Subroutine for Simulating Time-Varying Distribution Delays

a sequence with each subroutine simulating 50 pounds of growth. Upon exiting one growth phase model, the stocker immediately entered another growth subroutine. Each 50 pound growth model had its own unique growth parameters which were changed monthly to reflect seasonal changes in growth rates.

The delay length distribution generated by a VDEL model is characterized by the Erlang distribution. For the distribution, t, the Erlang family of density functions are given by:

$$(15)\ f(t) = \frac{(ak)^k (t)^{(k-1)} e^{-kat}}{(k-1)!}$$

The parameter, a, determines the mean of the distributions since

$$(16)\ E(t) = \frac{1}{a}$$

The variance of t is given by:

$$(17)\ Var(t) = \frac{1}{ka^2}$$

and the mode of t is:

$$(18)\ m = \frac{k-1}{ak}$$

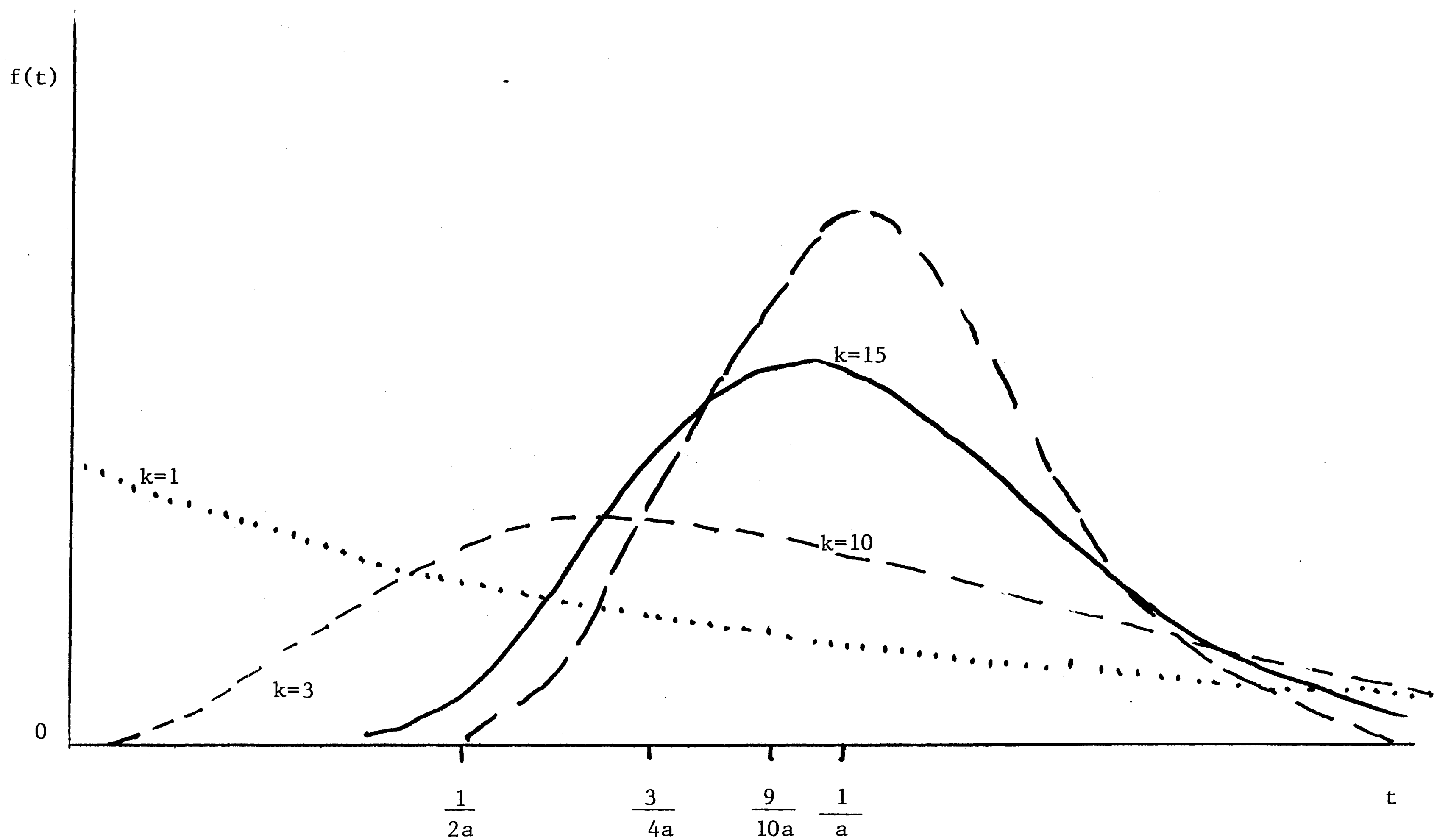
The parameter K defines the individual members of the Erlang family. The variance of an Erlang distribution is determined by its K-th order--where K is essentially the number of stages a flow (animal) must pass through to complete the delay. K values of greater than five or six cause the distribution to approximate a normal distribution, with smaller and smaller variances occuring as K increases. K values between 10 and 15 were found to produce the growth distribution felt to be descriptive of stocker cattle, with K=13 as ideal (Figure 3-5). Further documentation and discussion of distributed delays and the VDEL subroutine in specific can be found in Manetsch and Park (1974).

A complicating factor in selecting K is that the K level and time period of the model (referred to as DT in the systems literature) interact to determine the model's accuracy and cost of computation. According to guidelines developed by Forrester in his publication Industrial Dynamics a model's time period, or "delta t" and referred to as DT, must be specified as follows to assure computational accuracy in the delay model:

(19) (2 * Delay Length/K) > 4 * DT

Since the simulation model must be solved for every DT, the need to select a small DT will lead to considerable increases in computer time required to simulate a given time span. As a compromise between realism, accuracy, and computer time requirements, a K value of 10 and a DT of 0.00833333 (1/120) were selected. Thus with K equaling 10 the animals were expected to pass through 10 five-pound weight stages within each 50-pound VDEL delay. The model has approximately 120 iterations per year, giving it a three day time interval update.

Because the VDEL delay had 10 known stage (R), or stock (Q) inventories, it is possible to add to or attrition specific weight groups within the delay. By identifying weaned stockers by five pound increments, the stockers can be converted to flows and added to the appropriate VDEL delay 50-pound weight class at any time, i.e. at weaning. As described later, this ability allows the addition of



Source: Manetsch and Park (1974).

Figure 3-5. Erlang Family of Density Functions distributed weaned calves to stockers of similar weights that are previously existing in the delay. The ability to attrition the delay allows the sale of stockers at any point in time as well as accounting for death losses. Since growth rates are available for each month over the entire range of grassfed stocker weights, the VDEL delay is suitable for additional weaning periods.

This section described the general nature of the VDEL and DCTDEL delay models. VDEL and DCTDEL were modified and expanded to fit the needs of the model. The modifications are explained in more detail in the following sections.

Cow Herd Sector

The beef cow herd was basically modeled as a discrete delay process. Nearly all key parameters needed to describe the productivity of the cow herd were associated with the cow's age. Since aging is a fixed time length delay, the discrete delay model was a natural choice to use. Specific parameters used in the cow model were developed from the following sources. Average calf weaning weights by age of cow, cow weights by age, death rates of cows by age, and successful breeding rates by age were collected from various sources with King's (1979) research providing the primary reference (Table 3-1). An estimate of the time distribution of calving through the spring calving season was obtained from the Oklahoma State University Animal Science Department (Lusby). Policies for returning young cows that failed to wean calves were also based on information from the Animal Science Department.

TABLE 3 - 1

AGE RELATED PHYSICAL CHANGES IN COWS' PRODUCTIVITY

Cow Age	Calving Year	Average Weaning Weight	Birth Rate %	Death Rate %	Cow Weight	Steer Weaning Weight	Heifer Weaning Weight	in Cow Slaughter Price
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2	1	425	85.5	2.25	821	439.450	410.550	1.271
3	2	444	89.0	2.25	905	459.096	428.904	1.224
4	3	465	92.7	2.30	986	480.810	449.190	1.181
5	4	488	94.5	2.35	1041	504.592	471.408	1.140
6	5	488	94.3	2.45	1100	504.592	471.408	1.103
7	6	488	93.0	2.80	1100	504.592	471.408	1.067
8	7	488	90.8	3.25	1100	504.592	471.408	1.034
9	8	488	87.0	3.70	1100	504.592	471.408	1.003
10	9	488	82.0	4.35	1100	504.592	471.408	1.000
11	10	465	76.6	5.80	1100	480.810	449.190	1.000
12	11	465	70.0	6.30	1075	480.810	449.190	1.000
13	12	465	63.6	6.50	1050	480.810	449.190	1.000
14	13	465	56.2	6.60	1025	480.810	449.190	1.000
15	14	465	45.0	6.60	1000	480.180	449.190	1.000
16	15	465	41.0	6.60	1000	480.180	449.190	1.000

[1]Bently, Waters, Shumway, and King, 1979. [2]Rogers, 1971 and King, 1979. [3]Kay Rister, and King, 1979. [4]Avaerage Weaning Weight from Earnest, Shumway and Walters, and relative breakdown of heifer and steer weaning weights from Rogers, 1971, and King, 1979. [5]Rogers, 1971 and King, 1979.

The cows and replacement heifers are bred in June for March calving. Calving is assumed to occur over a period from February 15 through April 15, with the calf weaning weights reflecting the calving distribution and the brood cow's age. The calving distribution will be discussed in detail later. Cows are aged and culled when the calves are weaned in October (Figure 3-6).

The cow herd is aged by a discrete delay model, COWAGE. COWAGE is updated monthly and assumes one-twelveth of the annual death rate to occur each month. The COWAGE delay model maintains an array of cow inventories by age. These inventory values are modified each time period to reflect death and cullings. Cullings can be due to either performance failures or age. As recommended by Lusby, a cow is culled for performance reasons only after its second calving failure. Animal science research shows that approximately 20 percent of the calving failures in a given year are repeat failures. Thus, 20 percent of the cows having calving failures that are second calf cows or older are culled each year. The final culling age of the cow, regardless of previous performance, was left as a management policy to be analyzed.

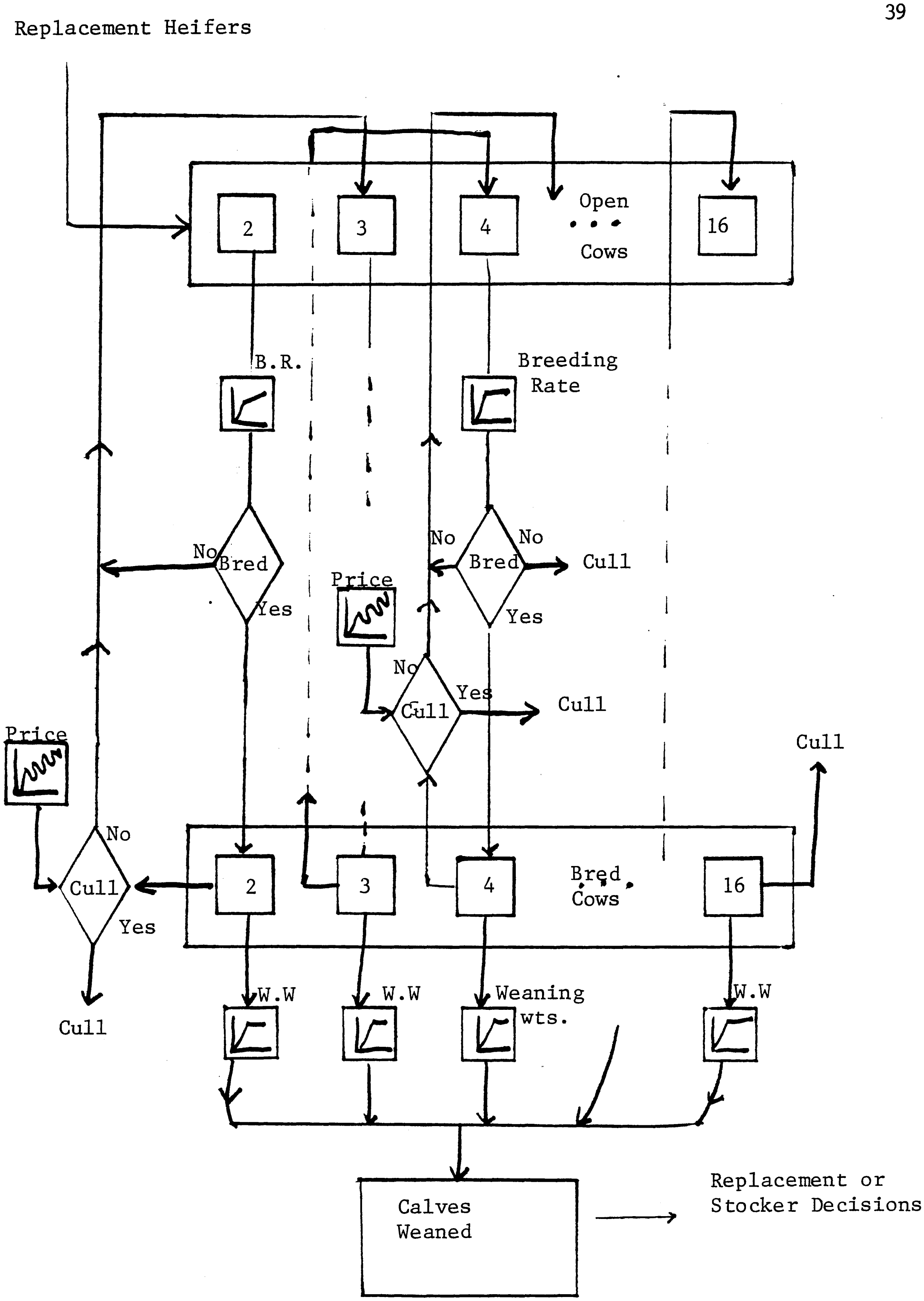


Figure 3-6. Unbred Cow Sector, Bred Cow Sector, and a Calf Weaning Sector of the Cow Herd Model

Specifically, COWAGE[1] keeps a running monthly total of the age and number of cows present on the ranch. At the end of the fiscal year surviving cows are aged as:

$$(20)\quad COWT(I+1) = COWT(I) - \left(\sum_{m=1}^{12} DR(I)/12\right)$$

where:

$COWT(I)$ = the number of cows of age I

$\sum_{m=1}^{12}(DR(I)/12)$ = the sum of the monthly death rates of cows of age I

m = the month of the fiscal breeding year

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[1]The COWAGE SUBROUTINE actually ages the cows in a reverse order array within the discrete delay, i.e. two-year old cows are placed under the array value COWT(15) thus signifying 15 years remain until the cow "naturally" would exit the delay if not culled by a management decision prior to then. For any given year, the aging process is programmed as:

$$(a)\quad COWT(J-1)=(COWT(J)x(1.0-(\sum_{m=1}^{12}DR(J)/12)))-(COWT(J)x0.2x(1.0-BR(J)))$$

where:

BR(J) = Breeding rate of cow of 16-J age

COWT(J) the number of cows of 16-J age

$\sum_{m=1}^{12} DR(J)/12$ the sum of the monthly death rates of cows of 16-J age

and (0.2x(1.0-BR(J))) = the second calving failures of cows of 16-J age where I > 2

m = the month of the fiscal breeding year

J = 16-I

I = age of cow by number of calves weaned

The performance culling process can be programmed as:

(b) CULL(J-1)=(COWT(J)x(1.0-(0.2x(1.0-BR(J)))))

where:

CULL(J-1)=culls of cows 16+1-I age due to productivity failures in the 16-I year

Performance failures from the preceding years are simultaneously culled and sold as shown in the equation below.

(21) CULL(I+1) =COWT(I)x(1.0-(0.2x(1.0-BR(I))))

where:

BR(I) = breeding rate for cows of age I

CULL(I+1) = performance culls of age I+1 and

(0.2x(1.0-BR(I)))

= the percentage of repeat failures for cows of age I

The COWAGE subroutine also keeps a running tabulation of replacement heifers needed to maintain a constant herd size. Throughout the year, the number of replacements needed to offset monthly death loss of cows is tabulated, and at weaning/culling time the number of cows culled are added to the needed replacements. Thus the number of replacements needed are calculated as:

(22) REP = COWT(I) x (DR(I)/12) + CULL(I)

where:

REP = needed replacement

and c = the management determined culling age

When calculating the number of weaned heifers to hold as replacements, these needs must be increased by two percent to allow for death during the one year replacement heifers are held in the replacement pool. Replacement heifers needed in a given year serve as a proxy for replacement needs of the following year. For the purposes of modeling a stable herd age distribution and constant herd size, the above heifer replacement needs calculation procedure resulted in the most consistent and stable cow herd age distribution. For unstable herd sizes, replacements and culls are allowed to vary according to economic criteria to be discussed later. In selecting replacement heifers from available weaned heifers, heavy weaned (feeder) heifers are considered more productive. Hence, the population of weaned heifers is sorted and preference is given to the heaviest heifers for the replacement pool. Weaned heifers not needed for replacement are classified as stockers. The replacement heifers are then aged through a discrete delay, REPLD, and enter the cow herd as bred cows.

The Calf Weaning Weight Distribution

Calf weaning weights were modeled to be influenced by calving date, sex and age of the brood cow bearing the calf. The weaning weights associated with each cow age used here are reported in Table 3-1. A distributing process was developed to integrate the effect of cow age upon weaning weight with the distributional affects of calving date. The purpose of this process was to develop a weaning weight distribution for each age of cow that would have a mean equal to the average weaning weight for that age of cow and a weight distribution around this mean consistent with the estimated calving distributions over the calving period. In this manner, a distribution of calf weaning weights for each age group of cows could be developed. These distributions could then be aggregated according to the number of cows in each age group that successfully calved and a total herd weaning weight distribution developed. A critical outcome of this process is that the average herd weaning weight, and weaning weight distribution for that manner, will change as the brood cow age structure changes. The following paragraphs describe the weaning weight distribution generation process in more detail.

The calf weaning weight distribution was designed to reflect the calf's age, sex, and the differences in the productivity of calves from different ages of brood cows. The basic guidelines used in constructing the distributions assumed a 1.0 lb. per day growth rate for a steer calved between February 15th and March 15th and a 1.66 lb. per day growth rate for a steer calved between March 16th and April 15th. Essentially, a steer calved on March 15th would weight approximately 450 lbs. when weaned on October 1st. If the same steer had been calved on February 15th, it would weight 480 lbs. on October 1st (1.0 lb. gain per day older). A steer calved on April 14th was assumed to weight 400 lbs. (1.66 lbs. less per day younger).

The calving distribution for a targeted mid-March calving period was assumed to place approximately 20 percent of the calves calved from February 15th to March 1, and equal proportions (40 percent each) calved in March and April. Implementing these guidelines required determining what percentage of the calf crop would be calved in each 15 day period over the 60 day calving season. It assumed that 20 percent would be calved between February 15th through March 1st. The remaining 80 percent of the calves would the be calved uniformly from March 2nd to April 16th (i.e. 80 percent/3 or 26.67 percent in each of the following three periods--March 2nd through 16th, March 17th through 31st, and April 1st through 15th). Combining the average daily gains with the calving date leads to the assumption that the heaviest calf weaned by a cow of age X would have been calved on February 15th.

Identifying B_1 as the weaning weight of a typical calf calved on February 15th leads to the identification of three basic groups of calves relative to this animal. Over a 60-day calving period (February 15th through April 15th), the calves are grouped as follows:

1. 20.0 percent of the calves would be calved in the first 15 days and average 7.5 lbs. less than B_1 (ranging in weight from 0.0-15.0 lbs. less);

2. 26.67 percent of the calves would be calved in the second 15 days and average 22.5 lbs. less than B_1 (ranging in weight from 15.0-30.0 lbs. less); and

3. 53.33 percent of the calves would be calved in the last 60 days and average 55.0 lbs. less than B_1 (ranging in weight from 30.0-80.0 lbs. less).

Information available from previous studies does not define the heaviest weaning weight, B_1. Rather what is reported is the average weaning weight. However, given the calving distribution and growth rates just described and the average weaning weight, the maximum weaning weight can be found. Assuming an average steer weaning weight of 450 lbs., the above information can be used to determine the maximum weaning weight, B_1:

$$(23)\quad 450 = 0.2 \times (B_1-7.5) + 0.2667 \times (B_1-15) + 0.5333 \times (B_1-55.0)$$

$$(24)\quad B_1 = 486.83225$$

Knowing the maximum weaning weight, B_1, the minimum weaning weight follows as B_1-80.0, or in this specific case 406.83 lbs. It also follows in general that the maximum weaning weight will equal the average weaning weight plus 36.83225 lbs.

The above formula can be expanded to describe the entire distribution of weaning weights given any average weaning weight. An example of this is given in Figure 3-7. The figure depicts a cumulative distribution function for weaning weights relative to a given maximum weaning weight value. The figure has three linear segments which relate the weaning weight of each animal with the timing of the calving distribution. Within each linear segment uniform daily calving rates and uniform daily gains are assumed. The segments are defined as follows starting from the maximum weight, B_1. Twenty percent of the calves will weight from 0.0 to 15.0 lbs. less than the heaviest calf, hence the first upper right linear segment of the cumulative distribution function runs from the coordinates (0.8, B_1-15.0) to coordinates (1.0, B_1). The middle linear segment represents the 26.67 percent of calves calved between March 2nd and March 16th which weigh from 15.0 to 30.0 lbs. less than the heaviest calf; hence this linear segment is plotted from (0.5333, B_1-30) to (0.8, B_1-15.0). The lower left hand segment represents the 53.33 percent of calves calved from March 17th through April 15th which weight 30.0 to 80.0 lbs. less than the heaviest calf. In general, the weaning weight cumulative distribution F(ww) is defined as follows:

(25) F(ww) = 0.000, for ww less than B_1-80.0

F(ww) = 0.5333, for ww less than B_1-30.0

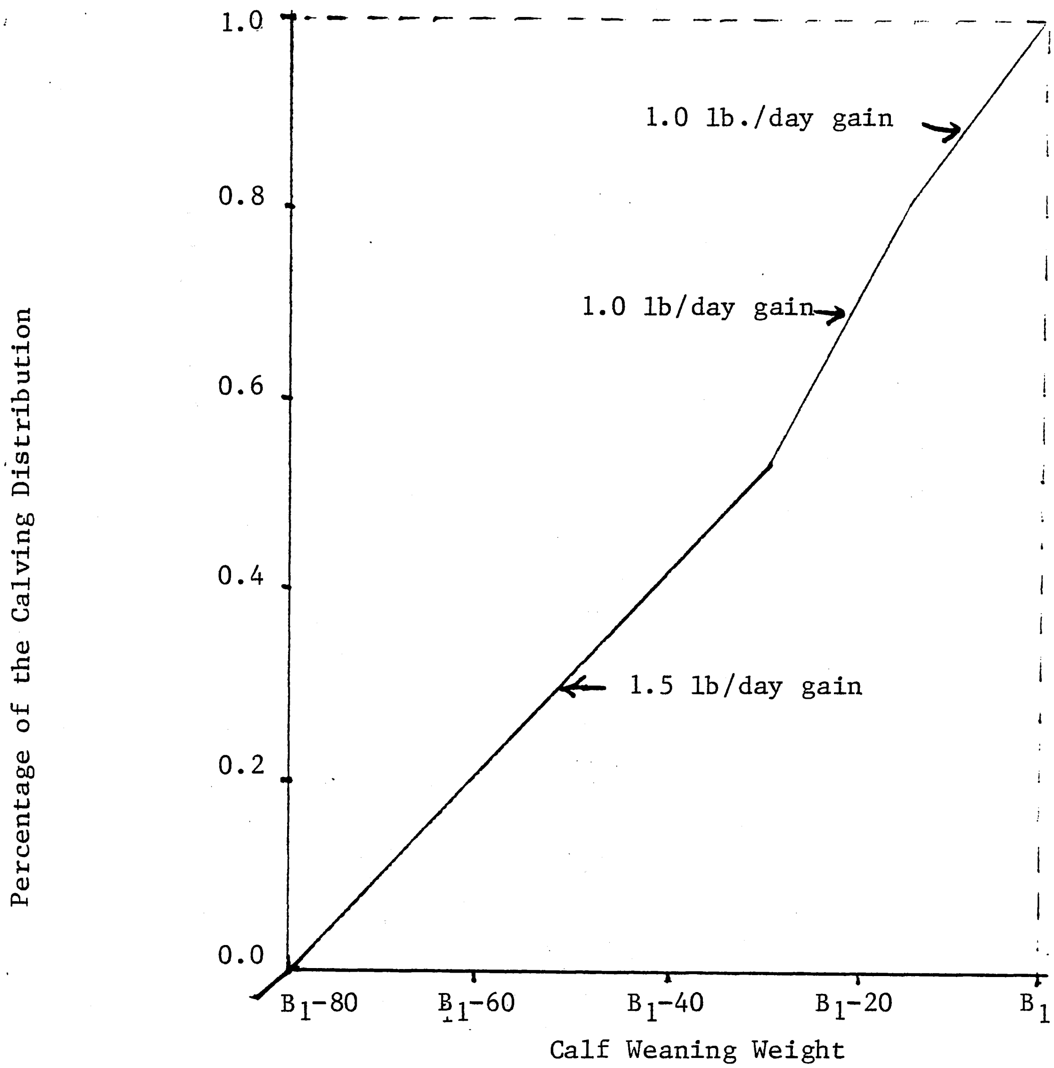


Figure 3-7. Cummulative Distribution Function for Calf Weaning Weights. The Three Slope Figure Indicates Calf Weaning Weights Dependent Upon Calving Date With 20.0 Percent of the Cows Calving Between February 15 and March 1, 26.67 Percent Calving Between March 2 and March 16, and 53.33 Percent Calving Between March 17 and April 15.

$F(ww) = 0.80$, for ww less than B_1-15.0

$F(ww) = 1.00$, for ww greater than or equal to B_1

where:

ww = calf weaning weight

B_1 = maximum value of calf weaning weights

The purpose of developing the cumulative weaning weight distribution function was to provide a method for grouping weaned calves into five-pound weight groups. Five-pounds is the weight interval present in the stocker growth/delay model, and hence the classification accuracy required to properly place weaned calves into the appropriate delay stage. The cumulative weaning weight distribution can be read to determine the percentage of animals in any given five-pound weight interval. Indeed a standardized simulation subroutine called Table-Lookup exists to read "table" values such as a cumulative weaning weight distribution of calves born with a given average weight and the total number of calves born, the number of calves in any five-pound weight class can be calculated and placed into an array as shown below.

(26) $NW(I) = (COW(A) \times WR(A)) \times (F(ww_i) - (F(ww_j))$

where:

NW(I) = number of calves in the I-th five-pound weight group weaned

COW(A) = number of brood cows of age A

WR(A) = percent of cows of age A successfully weaning a calf

$F(ww_i)$ = cumulative probability of a calf weighing less than the weight of the I-th five-pound weight level

$F(ww_j)$ = cumulative probability of a calf weighing less than the (I+1)-th five-pound weight level

Since different age groups of cows wean different weights of calves, a different cumulative weight distribution function with its uniqueaverage weaning weight is needed for each age group of cows. The procedure for deriving the weaning weight distribution is the same regardless of the weaning weight. Therefore; for each age group of cows, the indicated number of calves for a given five-pound weight class are placed in the appropriate stocker delay model weight inventory class. Thus the calves produced across all age groups of cows are aggregated in the stocker delay array. The aggregation results will be unique for each unique age distribution of cows in the herd.

The Stocker Growth Sector

The stocker growth sector (Figure 3-8) selects replacement heifers and grows grassfed stockers. The stockers can be sold at weaning as feeders or held as grassfed stockers. Upon becoming stockers, the calves are identified by their weight, sex, and grade. After identifying the steers and heifers in each weaning distribution, the calves are ready to be sold as feeders, used as replacement heifers, or grown as grassfed stockers. Because heavier heifers are often viewed as the most productive, weanling heifers are grouped into

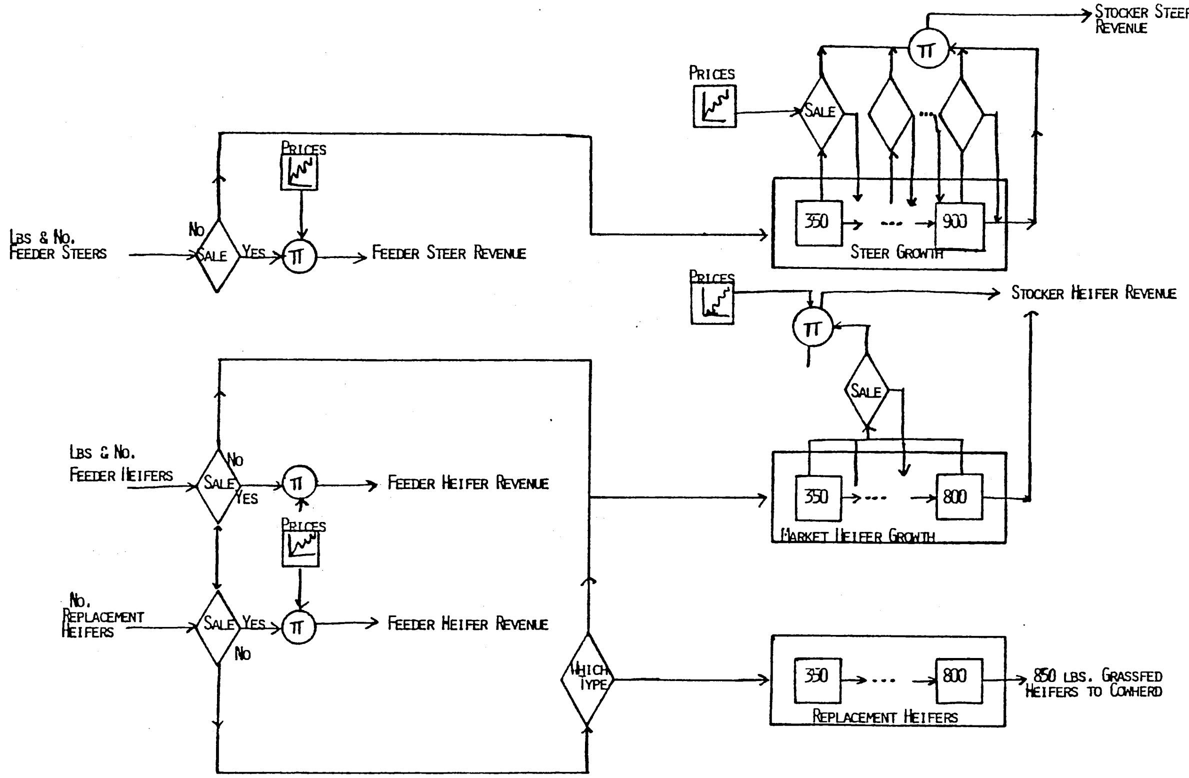


Figure 3-8. Stocker Sector of the Animal Model

29 five-pound weight groups. The model then selects the heaviest heifers to meet the replacement needs and classifies the excess, lighter-weight heifers as stockers. All steers and stocker heifers are sent to the variable length, continuous stocker growth delay model, VDEL. In VDEL, the delay length is a function of the stocker's monthly growth rates, the weight which the stocker is held, and the desired distribution variance.

Brorsen's model was consulted to determine stocker growth rates by age and season. There was enough variation in growth rates by weight (Table 3-2 and Table 3-3) to conclude that the growth rate used in the delay model should change as the stockers grow rather than remain one average rate. Hence, a cascade or sequence of continuous delay models was developed for each 50-pound weight group of animals. In this manner, the growth rate could be altered every 50 pounds. This degree of desegregation was thought to generate adequate accuracy in projecting stocker growth for given time spans.

The Cost Sector of the Model

The baseline model used in this research assumed a 100-head cow herd with adequate land and equipment to support such a herd. However, to evaluate different culling, replacement and stocker retention programs, the ability to accurately reflect changes in cost levels with various herd size and compositions was sought. Because this analyses focuses on intermediate run adjustments and decisions (five to ten planning years), the basic firm size was assumed to remain unchanged--that is the quantity of land, machinery, equipment,

TABLE 3 - 2

AVERAGE DAILY GROWTH BY MONTH AND STOCKER WEIGHT FOR STEERS AS GENERATED BY BRORSON'S MODEL USING NATIVE GRASS PASTURE AND THE CORN-SOYBEAN MEAL-ALFALFA HAY SUPPLEMENT

	Daily Growth by Months (Lbs)											
	Weight of Steer (lbs)											
	350 -399	400 -449	450 -499	500 -549	550 -599	600 -649	650 -699	700 -749	750 -799	800 -849	850 -899	900 -949
Jan	.120	.120	.130	.130	.140	.140	.140	.140	.140	.140	.140	.140
Feb	.160	.160	.160	.170	.170	.170	.170	.170	.170	.170	.170	.170
Mar	.190	.190	.190	.190	.195	.195	.195	.195	.195	.195	.195	.195
Apr	.195	.195	.195	.195	.200	.200	.200	.200	.200	.200	.200	.200
May	1.280	1.285	1.310	1.330	1.375	1.410	1.410	1.410	1.410	1.410	1.410	1.410
Jun	1.010	1.010	1.015	1.030	1.070	1.100	1.120	1.120	1.120	1.120	1.120	1.120
Jul	.780	.780	.780	.790	.820	.840	.865	.865	.865	.865	.865	.865
Aug	.675	.675	.675	.675	.675	.690	.700	.700	.700	.700	.700	.700
Sept	.690	.690	.690	.690	.690	.700	.710	.730	.730	.730	.730	.730
Oct	.450	.460	.480	.490	.500	.500	.500	.500	.500	.500	.500	.500
Nov	.110	.110	.110	.130	.130	.130	.130	.130	.130	.130	.130	.130
Dec	.090	.090	.100	.110	.110	.110	.110	.110	.110	.110	.110	.110

Source: Values generated by Brorsons Stocker Model when utilizing native grass pasture and the corn-soybean-alfalfa hay supplement developed by author and interpolations by author.

TABLE 3 - 3

AVERAGE DAILY GROWTH BY MONTH AND STOCKER WEIGHT FOR HEIFERS AS GENERATED BY BRORSON'S MODEL USING NATIVE GRASS PASTURE AND THE CORN-SOYBEAN MEAL-ALFALFA HAY SUPPLEMENT

	Daily Growth by Month (Lbs)									
	Weight of Heifer (lbs)									
	350 -399	400 -449	450 -499	500 -549	550 -599	600 -649	650 -699	700 -749	750 -799	800 -849
Jan	.115	.120	.120	.130	.130	.130	.130	.130	.130	.130
Feb	.150	.150	.160	.160	.160	.160	.160	.160	.160	.160
Mar	.180	.180	.180	.180	.180	.180	.180	.180	.180	.180
Apr	.185	.190	.190	.190	.190	.190	.190	.190	.190	.190
May	1.180	1.180	1.200	1.240	1.270	1.280	1.280	1.280	1.280	1.280
Jun	.940	.940	.960	.960	.990	1.010	1.010	1.010	1.010	1.010
Jul	.735	.735	.735	.735	.760	.790	.800	.800	.800	.800
Aug	.630	.630	.630	.640	.660	.660	.660	.660	.660	.660
Sept	.645	.645	.645	.650	.650	.660	.670	.680	.680	.660
Oct	.420	.430	.450	.455	.460	.460	.460	.460	.460	.46
Nov	.100	.100	.110	.120	.120	.120	.120	.120	.120	.12
Dec	.090	.090	.100	.100	.100	.100	.100	.100	.100	.10

Source: Values generated by Brorsons Stocker Model when utilizing Oklahoma native grass pasture and the corn-soybean-alfalfa hay supplement developed by author and interpolations by author.

and land improvements was fixed. Calculating the changes in variable costs required to efficiently manage herds of various sizes given these fixed conditions became the challenge of the cost section of the model.

U-Shaped Cost Curve

The U-shaped cost curve depicted in Figure 3-9 summarizes the cost per animal unit schedule used in this research. The low point of the per head total cost curve is reached with a 100-head cow herd or an equivalent set of animals with the same nutritional needs of a 100-head cow herd. Referring to Figure 3-9, variable costs per cow-equivalent unit and fixed costs per cow-equivalent unit were explicitly calculated within the model. Variable costs include costs of: bermuda hay forage replacement, supplemental feed, veterinary care, hauling, supplemental labor, and other variable costs. Fixed costs include machinery, equipment, and land charges, base labor charges, and other fixed costs attributed to the ranch and charged to each animal unit. The long-run average total cost per cow-equivalent unit (LATC) can be deducted from the variable cost and total fixed cost curves. The minimum point per cow-equivalent unit on the long-run average total cost curve is at 100 cow-equivalents. The costs were developed for 15 different herd sizes an linearly interpolated between to get the continuous functions. The long-run marginal cost per cow-equivalent unit (LMC) can also be deducted from the costs calculated by the model.

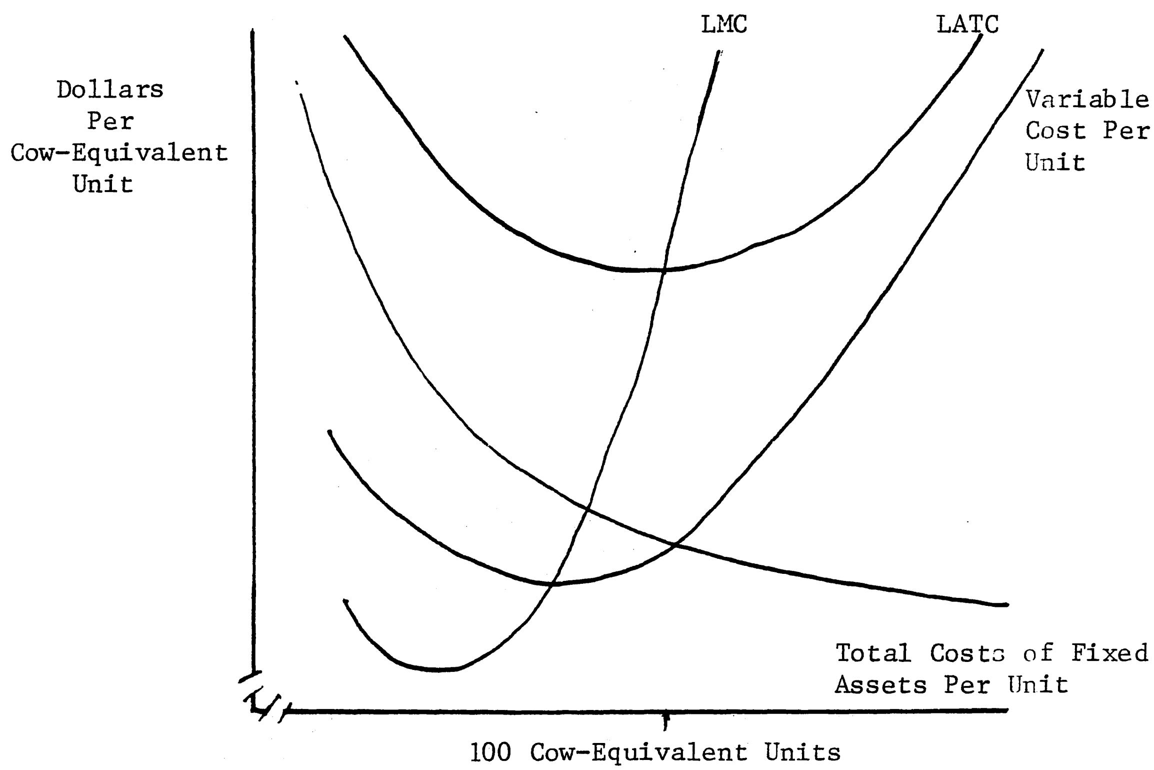


Figure 3-9. Continuous Approximation to the U-Shaped Cost Curve. The U-Shaped Cost Curve Represents the Costs Per Animal Unit. The Low Point of the Total Cost Curve is Reached with a 100-Head Cow Herd or the Equivalent

The focus of the research was a tall native grass ranch in northeastern Oklahoma. Forage availability and requirements, labor costs, supplemental feeding costs, other variable costs, and fixed costs were included. Specific cost parameters were developed from the following sources. Forage quality and availability as well as forage and supplement requirements for stockers and replacements were developed primarily from Brorson's (1981) study. Forage and supplement requirements for brood cows were developed from Fusselman's (1983) study. Supplement costs were developed from indexed Oklahoma State University 1979 budgets, and cyclical and seasonal estimated feed ration prices. Fixed costs and other variable costs were derived primarily from indexed 1979 Oklahoma State University budgets for native grass ranches in northeast Oklahoma. The three Oklahoma State University budgets utilized are titled:

1. "Cow Calf Cost and Returns/Per Cow, 100 Cow Units, Spring Calving/Dry Grass/Northeast,"

2. "Cow-Calf Cost and Returns/Per Cow, 100 Units Spring Calving, Carry Steers Through Winter and Sell in Spring/Cool Season Pasture/Northeast," and

3. "Stocker Budget/Per Calf, 50 Head Unit, Buy October-Sell August/Dry Grass Wintering Program, 300 Ownership/Pasture Charge Included/Northeast."

Additional sources of budget information included:

4. "Cow-Calf Cost and Returns/Per Cow, 100 Cow Unit Size, Spring Calving/Native Pasture/Central,"

5. "Cow Calf Cost and Returns/Per Cow, 25, 50, 100 Cow Units, Fall Calving/Cool Season Pasture/Eastcentral," and

6. "Cow Calf Cost and Returns/Per Cow, 25, 50, 100 Cow Units, Spring Calving/Febuary-March/East South Central."

Forage Model

The basic source of feed for the cow-calf-stocker herd was assumed to be native grass. Both Fusselman and Brorson's work have identified the seasonal nutrients that are available from native grasses. When seasonal forage quantity and/or quality were in deficit, a bermuda hay and/or a feed supplement consisting of corn, soybean meal, and alfalfa hay were fed. The hay was basically used to provide additional feed when pasture roughages available were not sufficient for prespecified intake requirements. The supplement was used to maintain the nutrient quality levels consistent with the growth rates assumed. The intake levels and nutrient requirements used were those specified by Fusselman and Brorson. The supplemental feed ration chosen was specified to serve as a replacement for grass when grass was in short supply due to seasonally low supplies or overstocking pressure. The general structure of the Forage Model developed is depicted in Figure 3-10. A detailed discussion of each of the components of this model will follow in the next two sections. Before discussing the components, the stocker growth curves that were generated to be compatible with the assumptions of the forage model will be briefly presented.

The stocker growth curves generated by the forage model rations used are depicted in Figure 3-11. The curves were developed from Brorson's model. The rations were used in Brorson's growth model and

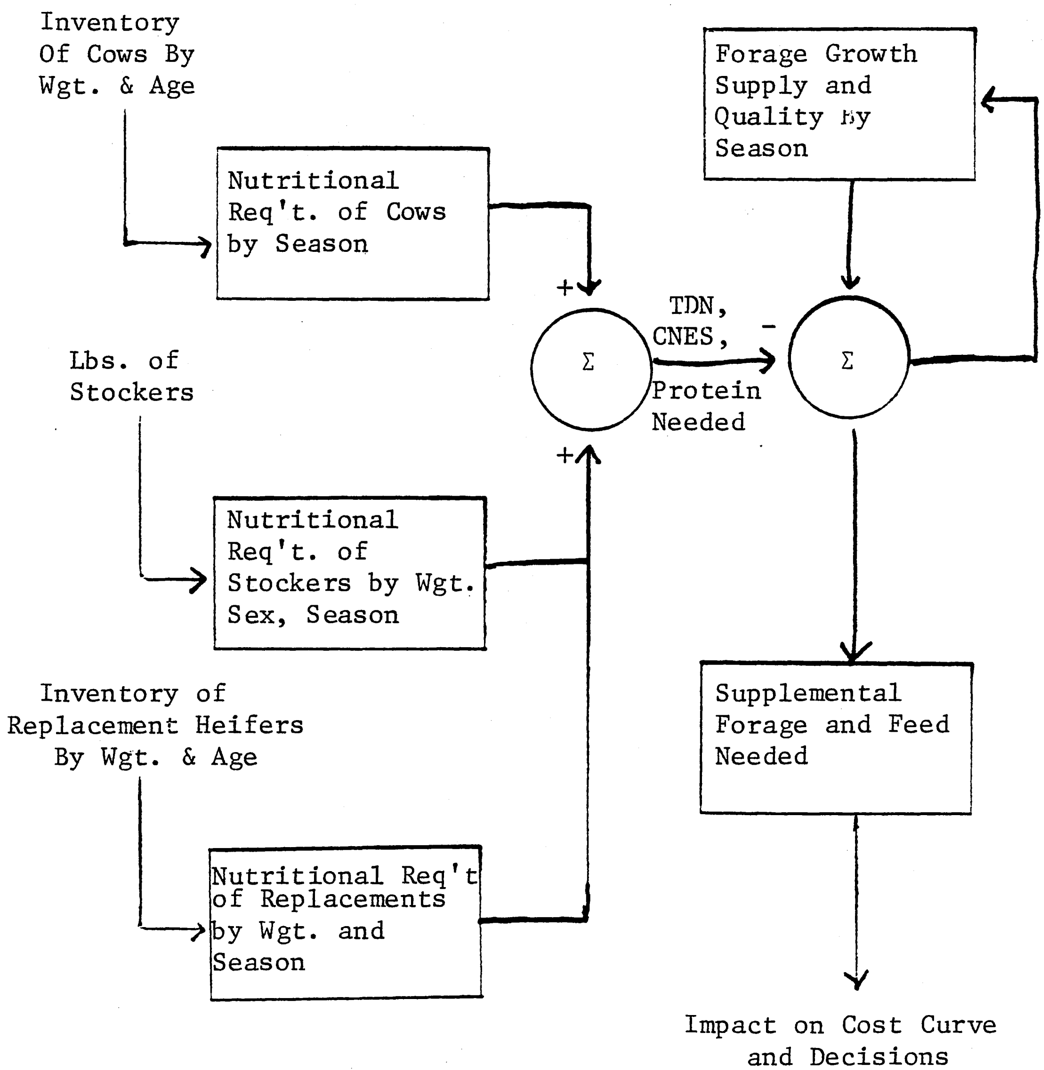
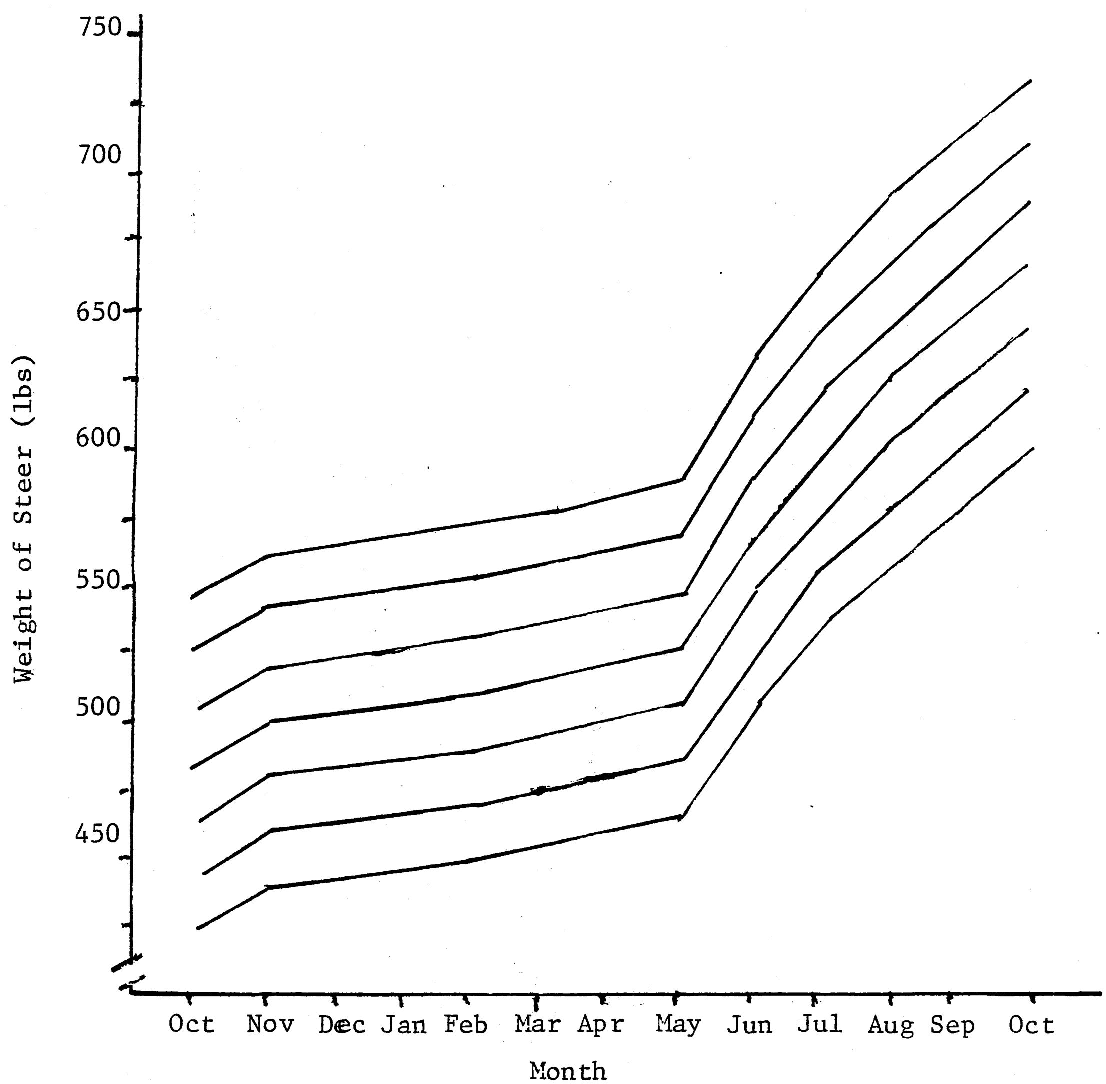


Figure 3-10. Forage Model



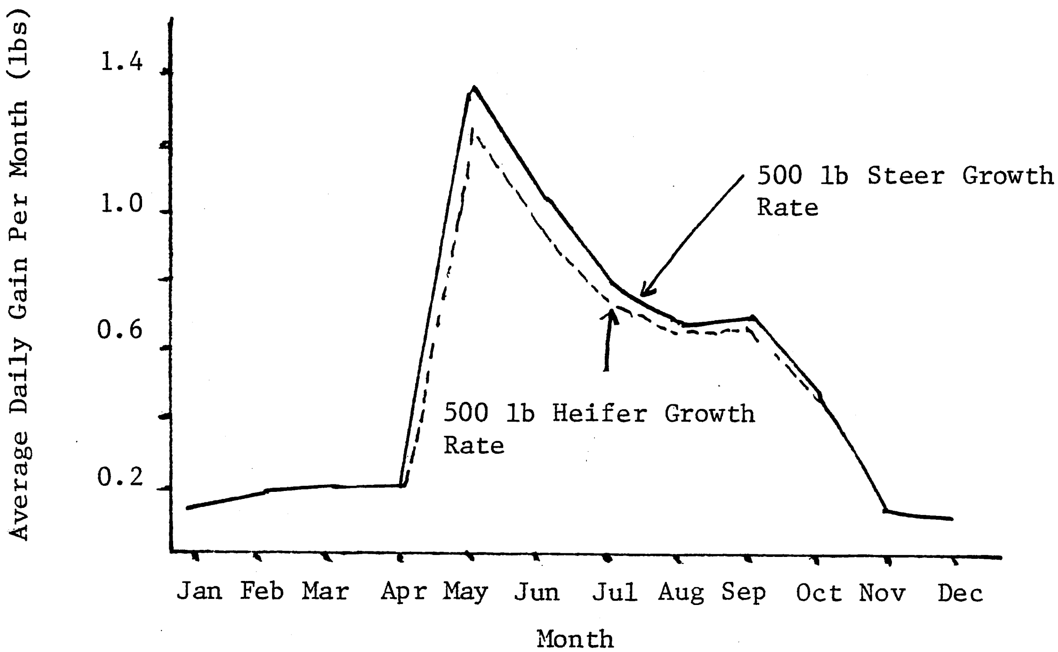
Source: Generated by Brorson's Model Utilizing Native Grass Pasture and the Corn-Soybean-Alfalfa Hay Supplement Developed by Author.

Figure 3-11. Steer Growth Projections

the resulting growth curves recorded. The data from the growth curves were then used to get the parameters of the various continuous delay models used to describe stocker growth. Figure 3-11 indicates the growth curves are similar for all weights of stockers. The steers averaged 0.1 to 0.2 lbs. per day gain from November through April. Daily gains then increase to between 1.0 to 1.5 lbs. per day for May and June and then drop to 0.78 to 0.865 lbs. per day for July. After July, average daily gains drop to between 0.45 and 0.70 lbs per day for August through October. This can be shown by a rapidly exploding growth curve for all steers (Figure 3-11) and the average daily gain curve for 500 lb. steers (Figure 3-12). Table 3-4 and 3-5 describe the growth rates used for steers and heifers in more detail. These two tables indicate that heavier animals actually grow slightly faster than lighter animals. The major courses of variations in growth rates are due to seasonality and sex.

The Forage Supply Components

The total forage available per month in the model was set equivalent to that indicated by the Oklahoma State University budgets and Fusselman's model for a 100-head cow herd. Table 3-4 describes the nutrients available per month for the native grass range used by the model. The ranch assumes 800 acres of native grass pasture or eight acres per cow. This quantity of pasture was selected because its normal carrying capacity would be approximately 100 cow-calf units. Referring to Table 3-4, pounds of dry matter yielded by the pasture increase over the productive summer months. The crude protein



Source: Values Generated by Brorson's Stocker Model When Utilizing the Corn-Soybean-Alfalfa Hay Supplement and Tall Native Grass Pasture and Interpolations by Author.

Figure 3-12. Average Daily Gain by Month for 500 lb. Steers and 500 lb. Heifers

TABLE 3 - 4

THE QUANTITY AND QUALITY OF FORAGE AVAILABLE BY MONTH FOR AN 800 ACRE TALL NATIVE GRASS RANCH AND FORAGE REQUIREMENTS BY MONTH FOR COWS[1] AND STOCKERS[2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Dry matter availability from tall native grass (lbs)	52000.0	52000.0	52000.0	52000.0	88000.0	88000.0	88000.0	88000.0	88000.0	52000.0	52000.0	52000.0
Percent crude proteins in tall native grass (%)	4.0	3.8	3.4	6.5	12.6	10.1	9.1	8.5	8.6	5.2	4.4	4.3
Aged cow forage requirement (lbs)	496.44	471.67	414.65	452.97	1036.06	967.31	936.73	966.50	1028.16	699.25	515.89	506.34
500-549 lb heifer forage requirement (lbs)	175.5	175.5	180.7	224.25	407.0	407.0	407.0	385.0	407.0	203.45	183.3	175.5
400-449 lb steer forage requirement (lbs)	162.5	162.5	166.4	216.45	392.7	329.7	392.7	392.7	392.7	180.7	159.9	158.6

[1]Cow requirements are foraged cows that were milking from mid-March through October 1 and pregnant from June through mid-March.
[2]Replacement heifer requirements followed those of 500 lb stocker heifers.

Source: Values generated by Brorson's Stocker Model and Fusselman's cow-calf model utilizing native grass pasture and corn-soybean meal-alfalfa hay supplement developed by author and interpolations by author.

TABLE 3 - 5

ADJUSTMENTS TO FORAGE REQUIREMENTS BY MONTH BY WEIGHT OF STOCKER

	Adjustment by Stocker Weight																				
	Adjustment to 400 lb Steer Requirement											Adjustment to 500 lb Heifer Requirement									
	350-399	400-449	450-499	500-549	550-599	600-649	659-699	750-799	800-849	850-899	900-949	350-399	400-449	450-499	500-549	550-599	600-649	650-699	700-749	750-799	800-[illegible]
Jan	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Feb	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Mar	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Apr	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
May	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Jun	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Jul	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Aug	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Sep	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Oct	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Nov	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18
Dec	1.0	1.0	1.12	1.16	1.2	1.24	1.28	1.32	1.4	1.44	1.48	.95	.95	1.0	1.0	1.06	1.06	1.12	1.12	1.18	1.18

Source: Values generated by Brorson's Stocker Model and Fusselman's cow-calf model utilizing native grass pasture and corn-soybean meal-alfalfa hay supplement developed by author and interpolations by author.

content of native grass pasture also changes by season ranging from a February low of 3.4 percent to a May maximum of 12.6 percent.

Figure 3-13 shows forage production and utilization. As shown by Figure 3-13 and Table 3-4 peak forage production and quality occurs in the summer months of May through September. Utilization of forage by all types of animals peaks over the summer months. Figure 3-14 shows the average daily supplement required to bring the native grass pasture up to minimal quality levels. In the summer months of May through August, brood cows derive all of the needed nutrients from forage so no supplemental feed is required. Maximum supplement utilization for brood cows occurs in March during the peak of the calving season as supplements are used to improve the quality and quantity of the pasture. Supplemental feed for the stockers is utilized throughout the fall and winter months (October through March) to improve the quality and quantity of the pasture. Again during the months of May through July, pasture forage meets the stockers nutrient requirement and no supplemental feed is needed. However; as the quality of the forage drops in late summer, small amounts of supplement are needed for stockers in August and September.

Nutrient Requirement Components

As depicted in Figure 3-13 and Figure 3-14 nutrient requirements for the herd are affected by the types of animals in the herd, their weight, age, sex, rate of gain and the season of the year. The basic nutrient requirement values used in this model by type of animal are reported in Table 3-4 and Table 3-5. Requirements for aged cows,

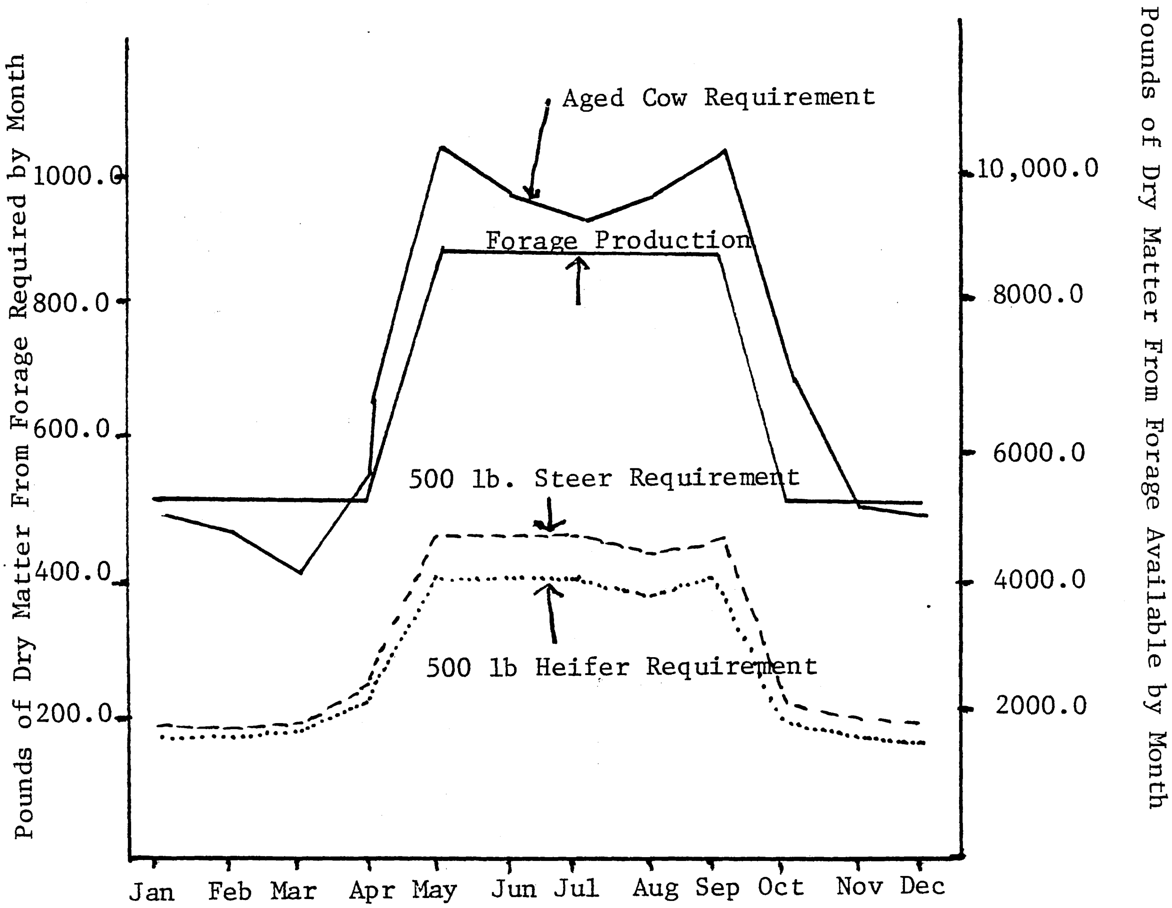


Figure 3-13. Forage Production by Month and Forage Utilization by Month for Aged Cows, 500 Lb Steers, and 500 Lb Heifers

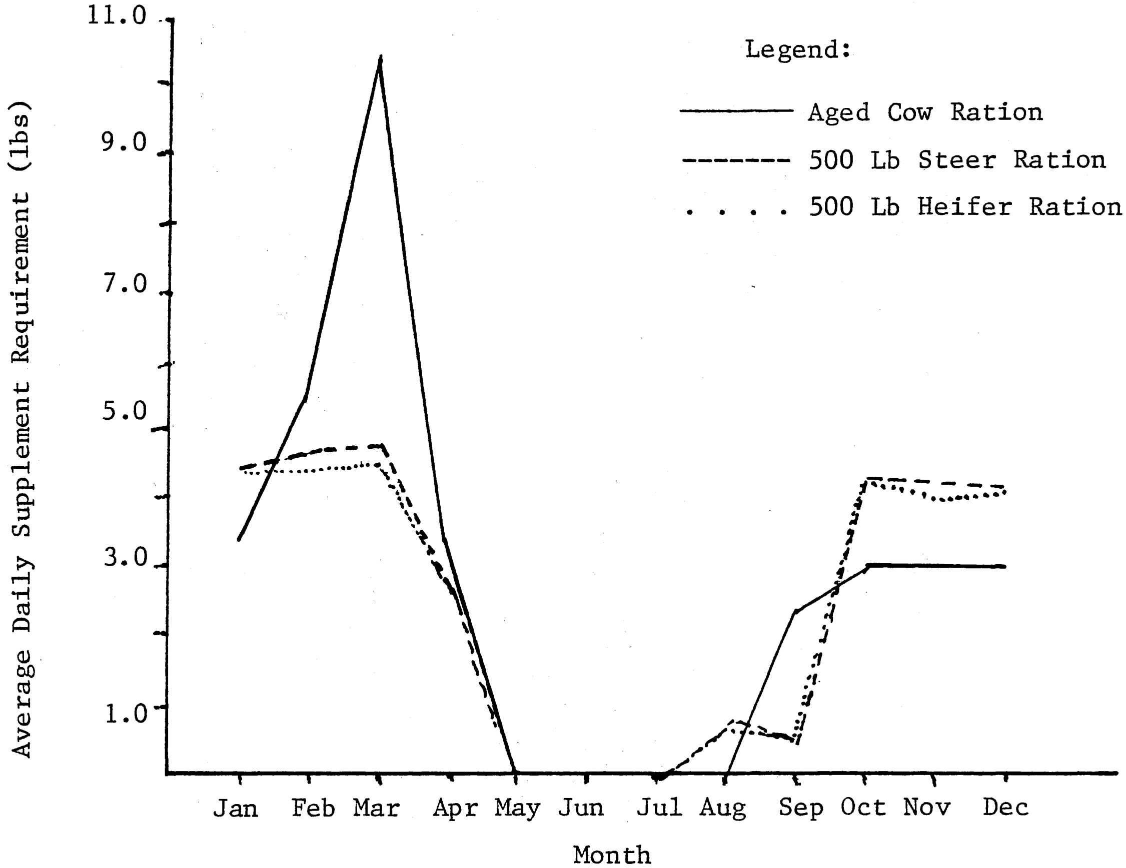


Figure 3-14. Average Daily Pounds of Corn-Soybean Meal-Afalfa Hay Supplement Required For Aged Cows, 500 Lb Steers, and 500 Lb Heifers

replacement heifers, 500 pound stocker heifers, and 400 pound stocker steers are given. In actuality replacement heifers and 500 pound stocker heifers are treated identically with regard to feed requirements. Differences in feed requirements by different aged cows were determined to be so small that special consideration of feed requirement by cow age was ignored. However, feed requirements by stocker weight differences were considered. Table 3-5 lists scaling factors used to adjust the base 500 pound heifer and 400 pound steer requirements. The rising feed requirements by weight reflect both the increased feed for maintenance requirement of heavier animals and the increase in feed needed by heavier animals because of slightly more rapid growth rate modeled for them (Figure 3-11).

Forage Deficiency

When management decisions lead to herd sizes that require more forage than the available pasture can produce, supplemental forage in the form of bermuda hay is automatically provided by the model. The deficiency level is calculated in terms of total herd deficiency by aggregating the forage requirements of the entire herd. Pounds of total forage needed were identified as used forage (UFRG). The difference between the amount of forage available and the amount of forage consumed in a given period was identified as excess or deficient forage (XFRG). Crude protein content was selected as the means of evaluating how much bermuda hay is needed to replace a given forage deficient. Bermuda hay is supplemented until the pounds of crude protein required from forage is satisfied. The pounds of bermuda hay supplement required for a given period's forage deficit are calculated as follows.

(27) BH = (XFRG x CPFRG(MO))/0.09

where:

BH = lbs. of bermuda hay needed

XFRG = lbs. of pasture forage deficient this period

CPRFG(MO) = Percentage of crude protein in tall native forage by month

9% = crude protein in bermuda hay

The needed bermuda hay is then charged a constant bermuda hay price. The variable cost associated with supplemental bermuda hay is allocated against cows, replacements, and stockers according to their feed requirement levels as given in Tables 3-4 and 3-5. Stockers were charged by each five-pound incremental weight group. It was assumed that all animals will eat bermuda hay, so it is charged in a similar manner to all. For example, costs charged to cows are calculated as:

(28) VCFCOW = (FCOW/UFRG) x VCBH

where:

VCFCOW = Variable cost charged to cows for forage

FCOW = forage and bermuda hay eaten by cows

UFRG = total forage and bermuda hay eaten, and

VCBH = total cost of supplemental forage (bermuda hay)

This allows the model to increase variable costs due to pressure on the pasture from overstocking. Understocking results in no variable costs due to forage; however, the fixed costs associated with owning pasture and other fixed assets will increase the per head cost when understocking occurs.

Supplement Costs Subsector

Feed supplements were utilized when needed to meet maintenance requirements for the animals. A corn-soybean meal supplement ration was used. The corn-soybean ration was composed of 2520 lbs. of corn and 270 lbs. of soybeans. Regression techniques were used to estimate cyclical and seasonal price relationships for the ration's cost. To provide a realistic supplement mix, 6000 lbs. of alfalfa hay were added to the ration to form a ration mix of 68.24 percent hay and 31.76 percent corn-soybeans. Because weather conditions often make hay prices irregular and unpredictable, alfalfa hay was charged a constant price and no attempt was made to describe the dynamics of hay prices.

Brorson and Fusselman's research indicates that supplemental feeding is provided on a per head basis to compensate for pasture quality deficiencies. The feed supplement used was designed so that productivity of the animals consuming the supplement was consistent and did not change with pasture pressure. The feed supplement then only increased the quality of the forage to minimal maintenance requirements.

TABLE 3 - 6

AVERAGE DAILY SUPPLEMENT OF CORN-SOYBEAN MEAL-ALFALFA HAY[1] REQUIRED TO RAISE THE NATIVE GRASS PASTURE TO MINIMAL NUTRITIONAL LEVELS FOR AGED COWS, REPLACEMENT HEIFERS AND STOCKER STEERS

Daily Requirements by Month (lbs)														
			Steer Weight (lbs)											
			350-399	400-449	450-499	500-549	550-599	600-649	650-699	700-749	750-799	800-849	850-899	900-949
Jan	3.38	4.40	3.89	3.91	4.19	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41	4.41
Feb	5.48	4.37	4.09	4.11	4.39	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.72
Mar	10.46	4.49	4.20	4.23	4.49	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72
Apr	3.39	2.70	2.63	2.63	2.66	2.68	2.68	2.68	2.71	2.71	2.71	2.71	2.71	2.71
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.44	0.77	0.77	0.77	0.52	0.52	0.27	0.06	0.00	0.00	0.00	0.00	0.69
Sept	2.38	0.00	0.52	0.52	0.52	0.52	0.23	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Oct	3.00	4.21	3.86	4.07	4.29	4.29	4.29	4.29	4.29	4.29	4.29	4.29	4.29	4.29
Nov	3.00	4.00	3.64	3.93	3.93	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22	4.22
Dec	3.00	7.00	3.67	3.96	3.96	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17	4.17

[1]The Supplement consists of 6000 lbs alfalfa hay, 2520 lbs corn and 270 lbs soybean meal.

Source: Values generated by Brorson's Stocker Model and Fusselman's Cow Herd Model utilizing Native Grass Pasture and the corn-soybean meal-alfalfa hay supplement developed by author and interpolations by author.

TABLE 3 - 7

AVERAGE DAILY SUPPLEMENT OF CORN-SOYBEAN MEAL-ALFALFA HAY[1] REQUIRED TO RAISE THE NATIVE GRASS PASTURE TO MINIMAL NUTRITIONAL LEVELS FOR STOCKER HEIFERS

Daily Requirements by Month (lbs)

Heifer Weights (lbs)

	350 -399	400 -449	450 -499	500 -549	550 -599	600 -649	650 -699	700 -749	750 -799	800 -849
Jan	4.07	4.07	4.17	4.40	4.40	4.40	4.40	4.40	4.40	4.40
Feb	4.27	4.37	4.37	4.37	4.37	4.37	4.37	4.37	4.37	4.37
Mar	4.39	4.39	4.39	4.49	4.49	4.49	4.49	4.49	4.49	4.49
Apr	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.69	0.69	0.69	0.69	0.69	0.69	0.44	0.44	0.44	0.44
Sept	0.51	0.51	0.51	0.51	0.51	0.40	0.13	0.13	0.00	0.00
Oct	4.07	4.07	4.21	4.21	4.21	4.21	4.21	4.21	4.21	6.62
Nov	3.82	3.82	4.00	4.00	4.00	4.00	4.00	4.00	4.00	6.56
Dec	4.17	3.86	3.86	4.05	4.05	4.05	4.05	4.05	7.00	7.20

[1]The Supplement consists of 6000 lbs alfalfa hay, 2520 lbs corn and 270 lbs soybean meal.

Source: Values generated by Brorson's Stocker Model and Fusselman's Cow Herd Model utilizing Native Grass Pasture and the corn-soybean meal-alfalfa hay supplement developed by author and interpolations by author.

Nutrient Requirement Components

Nutrient requirements for the herd are affected by the types of animals in the herd, their weight, age, sex, growth rate, and season of the year. The basic supplemental nutrient requirement values are reported in Table 3-6. Requirements for aged cows, replacement heifers, stocker steers, and stocker heifers were reported. As noted in Table 3-6 and Table 3-7 no supplemental feed is required for May through July as all required nutrients are provided by the native grass pasture. Heifers and light weight steers require supplement during August and September due to increased protein requirements for heifers and rapidly growing steers. For a given month heavier animals require increased feed requirements for maintenance and their more rapid growth rate. Increased supplemental feed requirements for cows between February and April reflect increased nutrient requirements associated with the calving period. Figure 3-14 shows the daily supplements required at different months in the year for aged cows, 500 lb. steers, and 500 lb. heifers.

Supplemental feeding was charged on a per head basis for all animals. Daily supplements required for stockers were generated by Brorson's model, and daily supplements required for cows were generated by Fusselman's model. Replacement heifer supplement requirements were set at that of 500 lb. heifers, and cow supplement was set at aged cow requirements.

Other Costs

In addition to forage costs, the firm faces labor costs and other variable costs including veterinary care, fuel consumption, machinery repair, taxes, operating costs, and fixed costs. Oklahoma State University budgets for 1979 were used to determine monthly cost and labor requirements. To make these costs compatible with the average 1958-1979 cattle price data utilized in the model, the "Index of Prices Paid by Farmers" was used to index the 1979 costs by item to 1969 levels.

Labor Costs and Requirements

Labor requirements were derived from the Oklahoma State University budgets and evaluated at \$1.35/hr. King's (1979) identification was used initially. King identified three-fourths of the total yearly labor as a fixed cost, and one-fourth of the total yearly labor as hired or variable costs. However, this did not hold for monthly labor costs since labor needs varied widely between months. Therefore, fixed labor charges for a 100-head cow-calf herd were set at the hours of labor required during the minimum labor requirement month (56 hours), and additional labor hours above this level for any month were charged as variable costs. Hence, fixed and variable labor requirements were determined monthly. Standard monthly labor requirements per head were developed for 100-head cow-calf herds and 50-head stocker herds. By using a method similar to that of King(1979), interpolation of Oklahoma State University budgets from various herd sizes were then used to develop adjustments in labor requirements by month for different herd sizes. The proportional adjustments to labor requirements varied by month and by herd size. The adjustment rates developed and used are reported in Table 3-8. The table indicates, for example, that a 100-head cow herd in January would require 0.72 hours of labor per cow or a total of 100 x 0.72 x 1.0 hours of labor, i.e. 72 hours. Given a fixed labor supply of 56 hours per month, 16 hours of hired or variable cost labor would be required during the month. On the other hand a 150 head herd would require 150 x 0.72 x 1.1125 or 120.15 hours of labor for the month, of which 120.15-56.0, or 64.15 hours would be variable cost labor. Labor requirements for replacement and stocker were also developed and are reported in Table 3-9. Replacements were charged the same labor rates as stockers. The rates and adjustment factors reported are interpreted in the same manner as those for cows.

Variable charges for labor were determined by the difference between total labor hours and fixed labor hours. This was done every three-day modeling period since herd size is subject to change every modeling period. Labor's cost was evaluated at $1.35/hr. The variable cost of labor is then distributed between cows,stockers, and replacements in a manner similar to that of forage charges.

This procedure generates a U-shaped variable cost curve with a minimum value at a herd size of 100-head of cow equivalents. It also allows fixed costs of labor to increase for small herds.

TABLE 3 - 8

THE PER ANIMAL LABOR HOUR REQUIREMENTS PER MONTH FOR COWS WITH ADJUSTMENTS FOR NUMBERS OF ANIMALS. THE LABOR REQUIREMENTS GENERATE A U-SHAPED LABOR COST CURVE[1]

		Number of Cows														
Month	Base # Hrs.	over 175.0	167.5 -175.0	150.0 -176.4	137.5 -149.9	125.0 -137.4	115.0 -124.9	105.0 -114.9	95.0 -104.9	85.0 -94.9	75.0 -84.9	62.5 -74.9	50.0 -61.5	37.5 -49.9	25.0 -37.4	less than 25.0
Jan	0.72	1.31	1.23	1.15	1.1125	1.08	1.045	1.015	1.0	1.015	1.045	1.08	1.1125	1.15	1.23	1.31
Feb	0.88	1.30	1.23	1.15	1.1125	1.08	1.045	1.015	1.0	1.015	1.045	1.08	1.1125	1.15	1.23	1.30
Mar	0.72	1.30	1.23	1.15	1.1125	1.08	1.045	1.015	1.0	1.015	1.045	1.08	1.1125	1.15	1.23	1.30
Apr	0.62	1.35	1.265	1.18	1.135	1.09	1.054	1.018	1.0	1.018	1.054	1.09	1.135	1.18	1.265	1.35
May	0.56	1.39	1.3	1.21	1.1688	1.10	1.0675	1.021	1.0	1.021	1.0675	1.10	1.1688	1.21	1.3	1.39
Jun	0.56	1.33	1.26	1.19	1.1425	1.10	1.057	1.019	1.0	1.019	1.057	1.10	1.1425	1.19	1.26	1.33
Jul	0.56	1.33	1.26	1.19	1.1425	1.10	1.057	1.019	1.0	1.019	1.057	1.10	1.1425	1.19	1.26	1.33
Aug	0.68	1.33	1.26	1.19	1.1425	1.10	1.057	1.019	1.0	1.019	1.057	1.10	1.1425	1.19	1.26	1.33
Sep	0.56	1.36	1.29	1.21	1.1575	1.10	1.0675	1.021	1.0	1.021	1.0675	1.10	1.1575	1.21	1.29	1.36
Oct	1.24	1.23	1.17	1.10	1.075	1.05	1.03	1.01	1.0	1.01	1.03	1.05	1.075	1.1	1.17	1.23
Nov	0.74	1.35	1.265	1.18	1.135	1.09	1.054	1.018	1.0	1.018	1.054	1.09	1.135	1.18	1.265	1.35
Dec	0.78	1.31	1.23	1.15	1.1125	1.08	1.045	1.045	1.0	1.045	1.045	1.08	1.1125	1.15	1.23	1.31

Source: 1979 Oklahoma State University Budgets and interpolations by author.

[1]The U-Shaped Labor cost curve has its lowpoint at 100 cows. [2]Labor charged to cows is calculated as the product of the labor adjustment for the number of cows in the herd, the base number of hours per cow, and the number of cows.

TABLE 3 - 9

THE PER ANIMAL LABOR HOUR REQUIREMENTS PER MONTH FOR REPLACEMENTS AND STOCKERS WITH ADJUSTMENTS FOR NUMBERS OF ANIMALS. THE LABOR REQUIREMENTS GENERATE A U-SHAPED LABOR COST CURVE

		Replacement and Stocker Labor Adjustment			
			Number of Stockers and Replacements[1]		
		over 100.0	75.0-100.0	75.0-25.0	less than 25
Jan	0.45	1.09	1.045	1.0	1.045
Feb	0.45	1.09	1.045	1.0	1.045
Mar	0.45	1.09	1.045	1.0	1.045
Apr	0.33	1.09	1.045	1.0	1.045
May	0.33	1.09	1.045	1.0	1.045
Jun	0.21	1.09	1.045	1.0	1.045
Jul	0.33	1.09	1.045	1.0	1.045
Aug	0.69	1.09	1.045	1.0	1.045
Sept	0.33	1.09	1.045	1.0	1.045
Oct	0.93	0.74	0.870	1.0	0.870
Nov	0.45	1.09	1.045	1.0	1.045
Dec	0.45	1.09	1.045	1.0	1.045

[1]Labor charged to stockers and replacements is calculated as the product of the labor adjustment for the number of stockers and replacements in the herd, the base number of hours per stocker replacement, and the number of stockers or replacements.

Source: 1979 Oklahoma State University Budgets and interpolations by author.

Other Variable Costs

Other variable costs per month were developed from the Oklahoma State University budgets. Per head costs of fuel-lube, machinery/other equipment, operating capital, salt, veterinary supplies, hauling, taxes, and other costs were charged to cows and stockers. Replacement heifers were charged as stockers. These costs, as used in the model, are reported in Table 3-10.

Total Fixed Costs

Using the Oklahoma State University budgets, machinery investment, ownership, equipment investment, land rental, and 56 hours of labor were charged per month. Monthly fixed cost charges were calculated to be $393.00 (Table 3-11). The fixed costs were then charged to stockers, replacements, and cows based upon their proportion of the total herd. As is typical, fixed costs per head decline as the herd size increases.

In the preceding sections care has been taken to point out how costs could be, and were, allocated to each animal type. This was done so that a basis would exist to evaluate the cost and revenue of each type animal, and hence its rate of net return over time. Such information provides the basis for implementing the theoretical culling and replacement criteria previously developed. The next three sections further detail how individual animal costs and revenues are determined and maintained by the model.

TABLE 3 - 10

THE PER ANIMAL MONTHLY VARIABLE COSTS EXCLUDING FORAGE, SUPPLEMENTAL RATION, AND LABOR COSTS

Costs Per Head Per Item ($)

	Other Variable Costs Per Cow ($)					Other Variable Costs Per Stocker or Replacement ($)				
	Fuel-lube	Repairs	Other	Operating Captial	Total	Fuel-lube	Repairs	Other	Operating Captial	Total
Jan	.09	.09	.24	.09	.51	.23	.19	.10	.98	1.50
Feb	.12	.17	1.22	.14	1.65	.23	.19	.10	1.00	1.52
Mar	.09	.09	.43	.19	.80	.23	.19	.10	1.00	1.52
Apr	.09	.09	.10	.23	.51	.15	.13	.10	1.03	1.41
May	.06	.06	.00	.24	.36	.15	.06	.10	1.04	1.35
Jun	.06	.06	2.22	.26	2.60	.08	.06	.10	1.06	1.30
Jul	.06	.06	.24	.28	.64	.15	.13	2.01	1.00	3.29
Aug	.12	.20	.66	.30	1.28	.38	.19	.10	1.00	1.67
Sept	.06	.06	.43	.31	.86	.37	.19	.10	1.00	1.66
Oct	.15	.16	.66	.00	.97	.54	.46	3.01	.92	4.93
Nov	.15	.16	.56	.03	.90	.23	.19	.10	.94	1.46
Dec	.12	.13	2.07	.08	2.40	.23	.19	.45	.96	1.83

Source: 1979 Oklahoma State University Budgets with prices indexed to 1969 values and interpolations by author.

TABLE 3 - 11

FIXED COSTS PER MONTH CHARGED TO THE RANCH[1]

Labor 56 hours @ $1.35/hr.	$76.00
Machinery	17.00
Equipment	50.00
Land	250.00
Total	$393.00

[1]The fixed costs are assumed to be those required for a 100 head cow-calf ranch.

Source: 1979 Oklahoma State University budgets indexed to 1969 values

Total Costs

The variable costs of labor, forage, supplement, other variable costs, and fixed costs are summed to determine charges attributable to cows, replacements, and each five-pound increment of stockers. This is done in each three day modeling period (henceforth referred to as "daily"), so that a current and cumulative per head cost is available. In the Cow Cost (COWCOS) subroutine daily costs are attributed to each age group of cows and to replacements as:

(29) DCOW(I) = (VCLC+VCFC+VCSC+VCOC+FCC)x(COWT(I)/COW)

where:

DCOW(I) = total costs for cow of age I

VCLC + VCFC + VCSC + VCOC

= total variable cost attributable to cows

VCSC = variable costs of supplemental feed attributable to cows

VCFC = variable costs of forage attributable to cows

VCLC = variable cost of labor attributable to cows

VCOC = other variable costs attributable to cows

COWT(I)/COW = proportion of cows of age 16-I

FCC = fixed costs attributable to cows

As well as daily costs, monthly and yearly herd costs are kept for cows and replacements.

In addition to total herd costs, per head costs are determined by dividing the costs per age group by the number of cows within the age group as:

(30) DCPCOW(I) = DCOW(I)/COWT(I)

where:

DCPCOW(I) = total daily costs per cow of age I

DCOW(I) = total daily costs for all cows of age I

COWT(I) = number of cows of age I

Records are kept of the total costs per head over the life of the cow as well as daily, monthly, and yearly per head costs.

Total Stocker Costs

Daily costs of stockers directly influence the decision of whether to sell stockers or to hold stockers for sale at a later date i.e. the incremental increase in the value from holding a stocker should offset the costs associated with holding the stocker. As daily costs for the ranch are determined by the number of animals held on the ranch, the decision to hold a stocker an additional day directly influences the costs associated with brood cows, replacements, and other stockers. Thus stocker costs--primarily costs associated with pasture pressure--determine the size of the brood cow herd.

Daily stocker costs were calculated for five-pound increments within each 50-pound stocker weight group. Variable costs of labor, forage, and feed supplement, other variable costs, and fixed costs were charged to stockers.

In addition to daily costs, cumulative costs per head over the life of the stocker are important. Timing of stocker sales, a stocker's contribution to "spreading" fixed costs or increasing variable costs, and pragmatic herd management strategies use cumulative costs in determining net returns from stockers or a stocker's contribution to the ranch.

Because stockers grow and move through a series of cascaded delays, it was necessary to relate cumulatives costs to the movement of stockers through the cascaded delays. Only in this way could the correct cost calculations be associated with the correct animal. To relate the cumulative costs to movements of the growing stockers, daily costs were calculated for each five-pound group of stockers. The daily costs, then, were added to the cumulative costs for each five-pound stocker group. However; the stockers were moving within the cascaded VDEL delays and were not necessarily within the same five-pound group for consecutive periods. A stocker's cumulative costs, then, must flow through the cascaded VDEL delays simultaneously with the stocker and remain charged to the correct stocker. Allowing the cumulative stocker costs to be distributed through the cascaded VDEL delays in the same manner as the stockers provided the means for linking cumulative costs with individual stockers.

Stocker Cost Calculations

The stocker cost subroutine, STKCOS, calculates the cumulative costs for each five-pound weight group of stockers. Within STKCOS daily costs are converted into cost flows for use in the VDEL delays[1]. The daily costs flows are then added to the cumulative

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[1] As with the stocker growth subroutines, the costs are distributed in a K-th order Erlang distribution of 10.

cost flows for the appropriate five-pound weight group. The costs flows are then moved forward in the VDEL delay by a method similar to that of stocker flows.

Determination of the Animal's Value

The next sector of the model places a value on the cattle. Price estimates were made for feeder steers, the steer-heifer price spread, and cull (commercial) cows. Weight, grade, type, feed ration, sex of the animal, and cyclical and seasonal relationships were determined.

The feeder steer price prediction equation explained 71.53 percent of the feeder steer price variation. Intercept, time trend, sine and cosine cycle estimates, and steer weight variables were important in estimating the steer price prediction equation. Monthly discounts or premiums and ration price were beneficial in explaining steer price relations (Table 3-12). Feeder steer price relations will be discussed in more detail later.

Following King's (1979) recognition that feeder heifer prices are discounted feeder steer prices, a steer-heifer price spread prediction equation was estimated. The steer-heifer price spread (discount) equation explained 68.16 percent of the heifer price discount. Feeder steer price entered strongly in the steer-heifer price spread equation. Ration cost and heifer weight variables were also important. The steer-heifer price spread narrows as the heifer's weight increases and in typical replacement months of June, July, and August. The steer-heifer price spread widens as ration costs increase, further discounting the less efficient heifers. The heifer price discount tends to widen over time (Table 3-13).

TABLE 3 - 12

THE FEEDER STEER PRICE PREDICTION EQUATION

Variable	Parameter	T-Value
(1) Intercept	38.83798993	24.68
(2) February	0.56114574	1.09
(3) March	1.09827920	2.13
(4) April	1.63171287	3.16
(5) May	1.74368370	3.38
(6) June	1.25637247	2.43
(7) July	1.08581726	2.10
(8) August	1.17930872	2.28
(9) September	0.59043638	1.14
(10) October	0.35337519	0.68
(11) November	0.11236778	0.22
(12) December	-0.09516496	-0.18
(13) Time in Months	0.06757818	26.16
(14) Cosine of Cycle	2.35933768	13.53
(15) Sine of Cycle	3.58108493	21.61
(16) Weight of Steer	-0.04674142	-13.35
(17) Steer Weight Squared	0.000024076268	11.52
(18) Type Dummy for Fat Cattle Weight Discount	-3.43555518	-5.62
(19) Ration Cost	0.00281715	0.27
(20) Weight-Ration Interaction	0.000075589704	7.06

F Value =219.49. Cycle Length = 12 years. R^2 = 0.715284

TABLE 3 - 13

THE FEEDER STEER-HEIFER PRICE SPREAD PREDICTION EQUATION

Variable	Parameter	T-Value
(1) Intercept	-10.30971378	-11.48
(2) February	0.17417804	0.82
(3) March	0.31357027	1.48
(4) April	0.05979767	0.28
(5) May	0.09909676	0.46
(6) June	-0.05119386	-0.24
(7) July	-0.21869013	-1.03
(8) August	-0.03284379	-0.15
(9) September	0.01855918	0.09
(10) October	0.22338602	1.05
(11) November	0.17011076	0.80
(12) December	0.16408337	0.77
(13) Time in Months	0.00309793	2.43
(14) Cosine of Cycle	0.07703910	1.01
(15) Sine of Cycle	-0.58304225	-7.50
(16) Weight of Heifer	0.02653922	12.36
(17) Heifer Weight Squared	-0.000019947839	-14.44
(18) Type Dymmy for Fat Cattle Weight Discount	2.52865591	13.21
(19) Ration Cost	0.05750254	11.42
(20) Weight-Ration Interaction	-0.00010860	-16.73
(21) Feeder Steer Price	0.18758305	19.87

F Value = 126.21. Cycle Length = 12 years. R^2 = 0.681624

The cull cow price prediction equation explained 85.14 percent of the variation in commercial/cutter/canner cow prices. Intercept, sine, cosine, and trend variables entered strongly into the cull cow price equation (Figure 3-15). June was the highest priced month to sell cull cows with June cull prices bringing $1.88 over January prices (Table 3-14 and Figure 3-16).

The supplemental feed grain price prediction equation for estimating the corn-soybean meal portion of the supplemental ration cost explained 78.75 percent of the variation in the feed supplement prices. A sharp increase in price by month led to a sharp trend in ration price. The intercept, sine, and cosine cycle variables entered strongly in the feed grain price equation. Combining the trend and cycle variation led to a ration price with a long upphase and a short downphase (Figure 3-17). For the supplemental ration mixture of 270 pounds of soybean meal and 45 bushels of corn, August returns were $3.62 above January returns (Table 3-15).

Specific relations of the feeder steer price equation will be discussed and serve as a general model for explanation of feeder steer and feeder heifer prices. The basic feeder steer price relationship equation contains 20 variables and an intercept term. Monthly price data over the period 1958 through 1977 for six weight categories and various grades of cattle were used--Kansas City data was used for feeder steers, Omaha data was used for slaughter steers.

Variables two through 12 describe the estimated seasonal pattern for feeder steer prices and are consistent with previously reported seasonal patterns (Franzmann - 1971 and Hummer et al. - 1972). Figure 3-18 depicts the seasonal price pattern reflected by the variables.

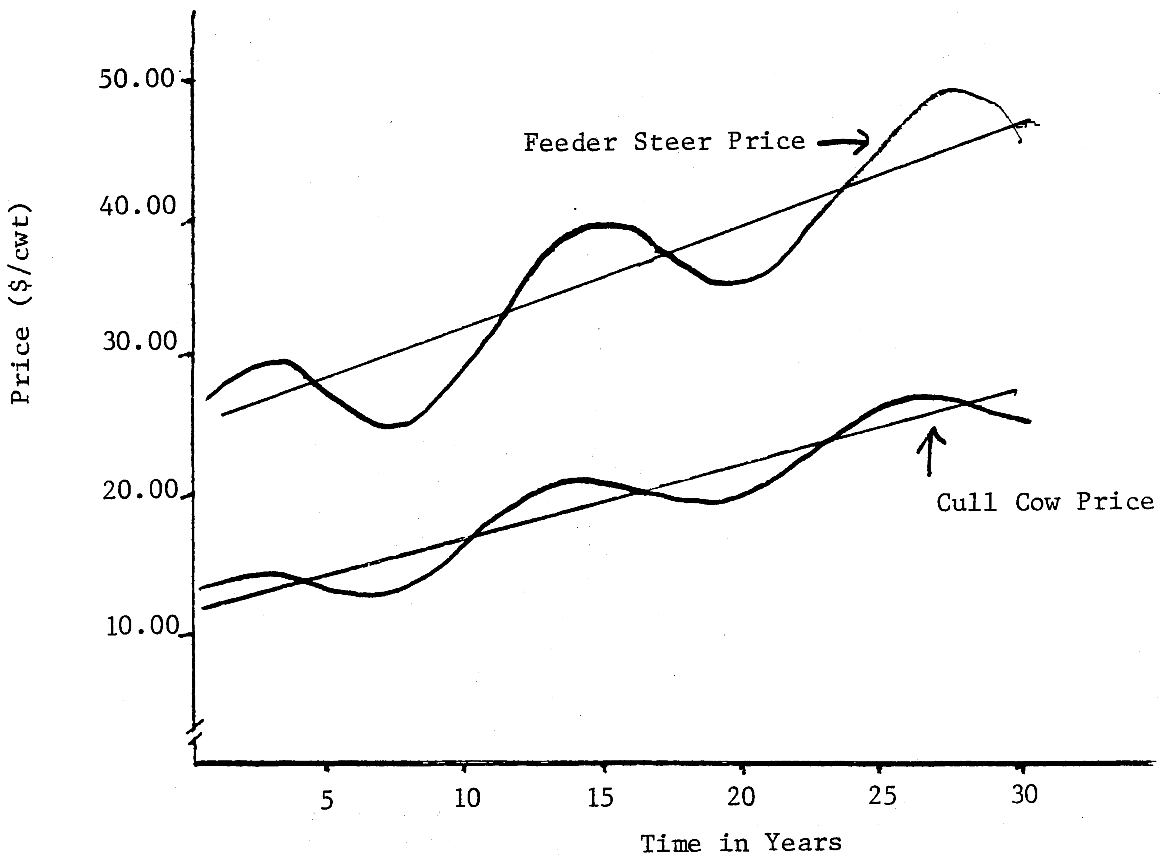


Figure 3-15. Cyclical and Trendular Price Patterns for 600 Lb. Choice Feeder Steers and Cull Cows

TABLE 3 - 14

THE CULL COW PRICE PREDICTION EQUATION

Variable	Parameter	T-Value
(1) Intercept	11.36305065	30.69
(2) February	0.80360778	1.71
(3) March	1.53730950	3.28
(4) April	1.54843835	3.30
(5) May	1.85165935	3.95
(6) June	1.88230277	4.02
(7) July	1.26703079	2.70
(8) August	1.27650412	2.72
(9) September	1.19471543	2.55
(IO) October	0.47498927	1.01
(11) November	-0.43201781	-0.92
(12) December	0.33231735	-0.71
(13) Time in Months	0.04372271	22.15
(14) Cosine of Cycle	1.83070287	12.79
(15) Sine of Cycle	1.20944813	8.39

F Value = 67.50. Cycle Length = 12 years. R^2 = 0.851359.

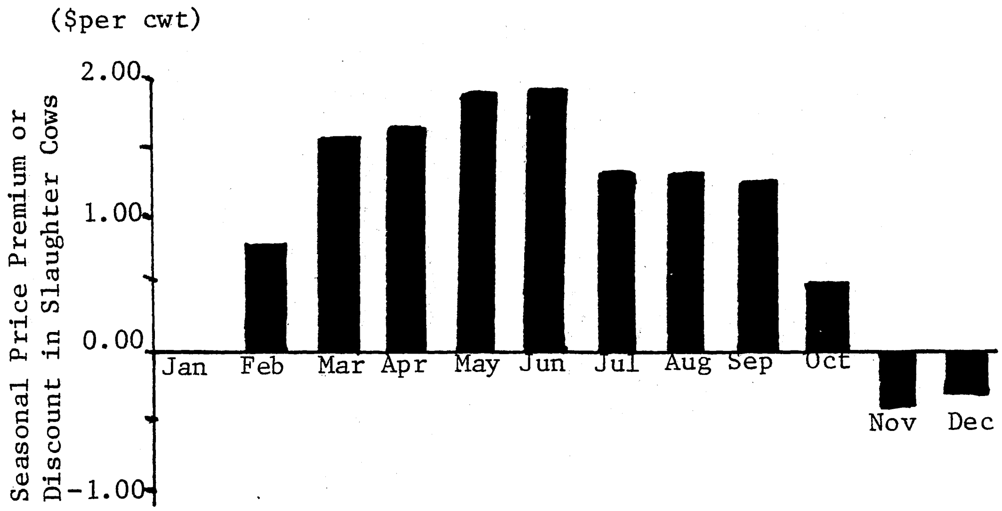


Figure 3-16. Monthly Variation in Cull (Slaughter) Cow Price From January (January = 0.0)

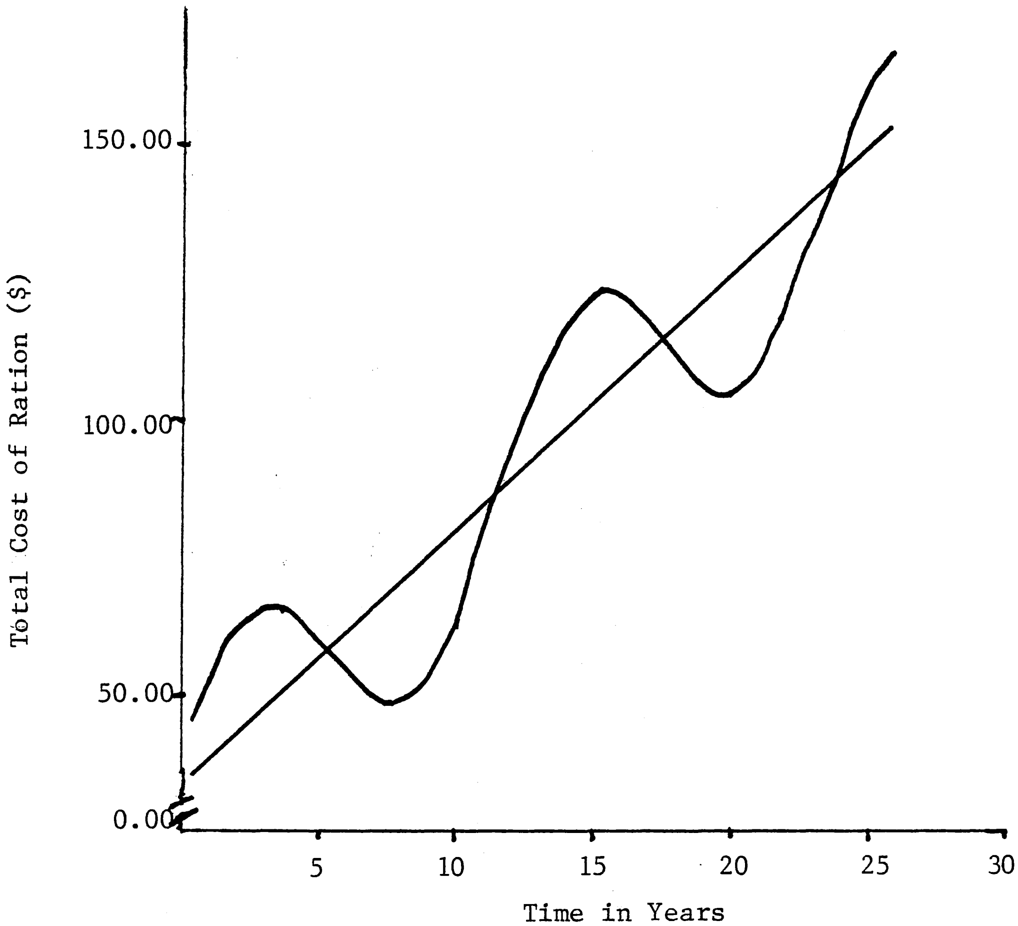


Figure 3-17. Cylical and Trendular Patterns of Ration Costs. Ration is Composed of 45 Bu. Corn and 270 Lbs. Soybean Meal

TABLE 3 - 15

THE SUPPLEMENTAL FEED GRAIN PRICE PREDICTION EQUATION

Variable	Parameter	T-Value
(1) Intercept	31.55206434	7.69
(2) February	-0.04995615	-0.01
(3) March	-0.70698062	-0.14
(4) April	-0.91350427	-0.18
(5) May	0.65218596	0.13
(6) June	2.48489696	0.48
(7) July	2.26087938	0.43
(8) August	3.62337755	0.69
(9) September	0.95732947	0.18
(10) October	-2.51793327	-0.48
(11) November	-6.14448551	-1.18
(12) December	-2.93065859	-0.56
(13) Time in Months	0.39506909	25.25
(14) Cosine of Cycle	6.25156829	3.94
(15) Sine of Cycle	20.12594313	13.19

F Value = 59.56. Cycle Length = 12 years. $R^2 = 0.787501$.

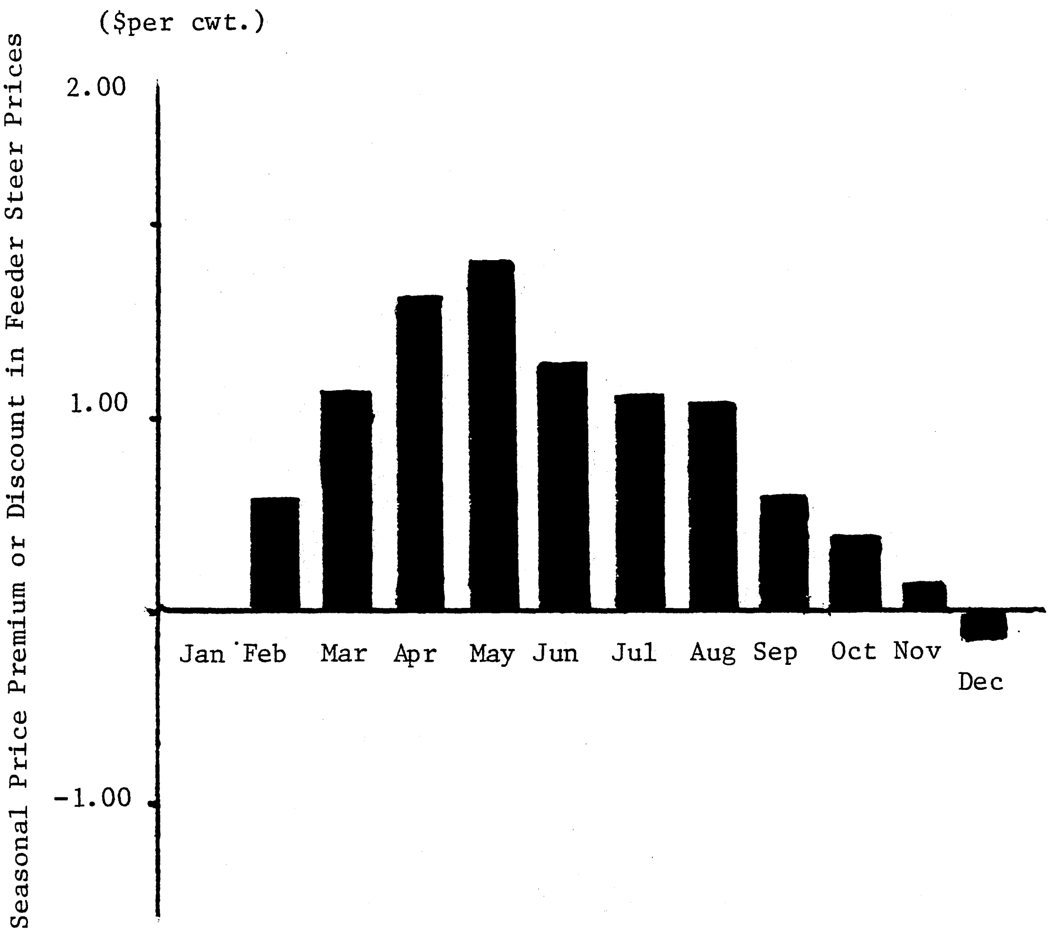


Figure 3-18. Monthly Variation in Feeder Steer Prices From January, (January = 0.0)

The peak of seasonal prices occurs in May, declines during the summer months, and bottoms in December. May yields $1.74 per cwt over the January price and $1.84 per cwt over the fall December price.

Variables 13 through 15 define the estimated trend and cycle patterns of feeder steer prices over time. An upward trend of 6.76 cents per cwt per month, or 81.12 cents per cwt per year, is indicated by the trend variable. The two cycle variables combine to indicate a 12-year cycle. Experimentation with various cycle lengths indicated a cycle of 12 to 15 years with the 12-year length selected. The data period considered is only 20 years in length and is not long enough to be strongly confident in the estimated cycle length. Thus, strong consideration was given to cycle lengths found by other researchers (as reported in the literature review) in selecting the cycle length to be used in the model. Lack of consistent data being available prior to 1958 prevented a longer period from being considered. Figure 3-15 graphically portrays the trend and cycle patterns found. Variables 16 through 18 quantify the relationship between increasing steer weight and feeder steer price.

Variables 19 and 20 describes the impact of changing ration costs on feeder steer prices. Ration cost is determined in this case as the combined value of 270 pounds of soybean meal and 45 bushels of corn. Ration prices calculated in this manner ranged from $51.91 to $192.33 over the period 1958 through 1977. When Ration prices were detrended by fixing the trend at January 1969 levels, ration prices cyclically vary from a peak of $104.76 to a bottom of $62.63 (Figure 3-19). Since feed utilization efficiency is directly related to weight, a

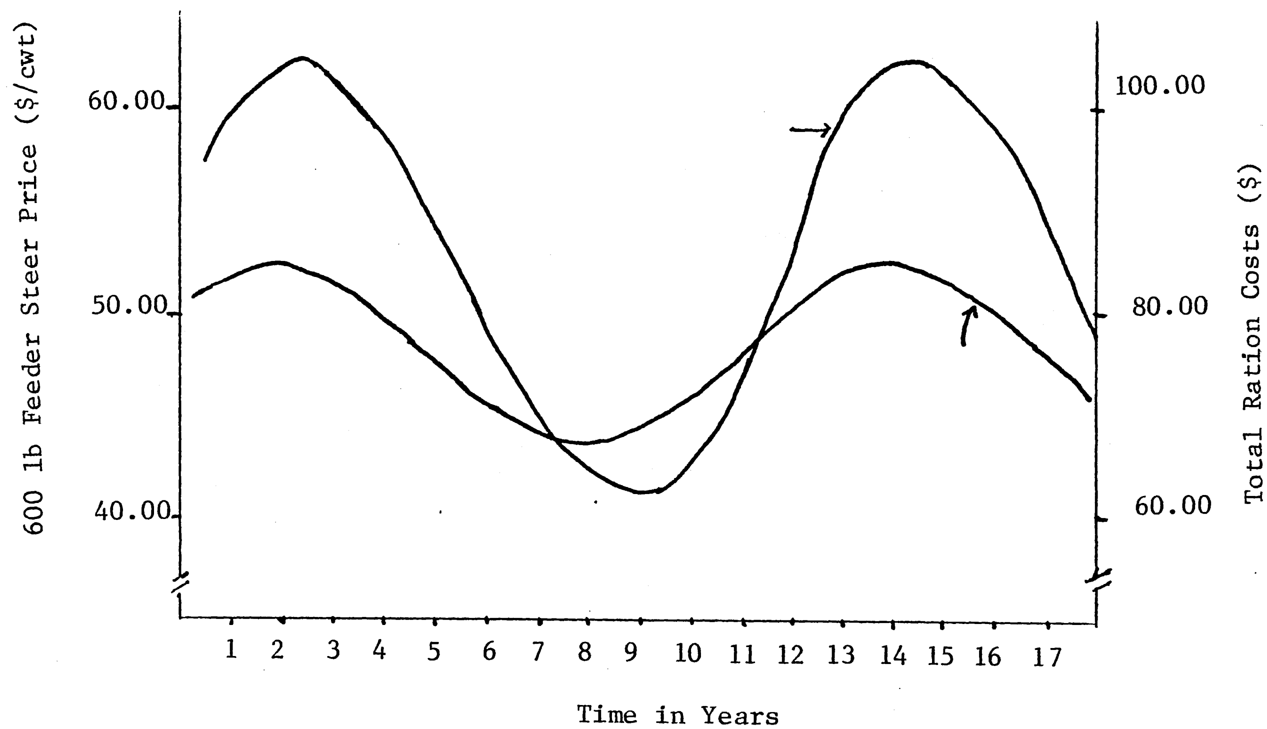


Figure 3-19. Price Tendencies for 600 lb. Feeder Steers and Ration Supplement

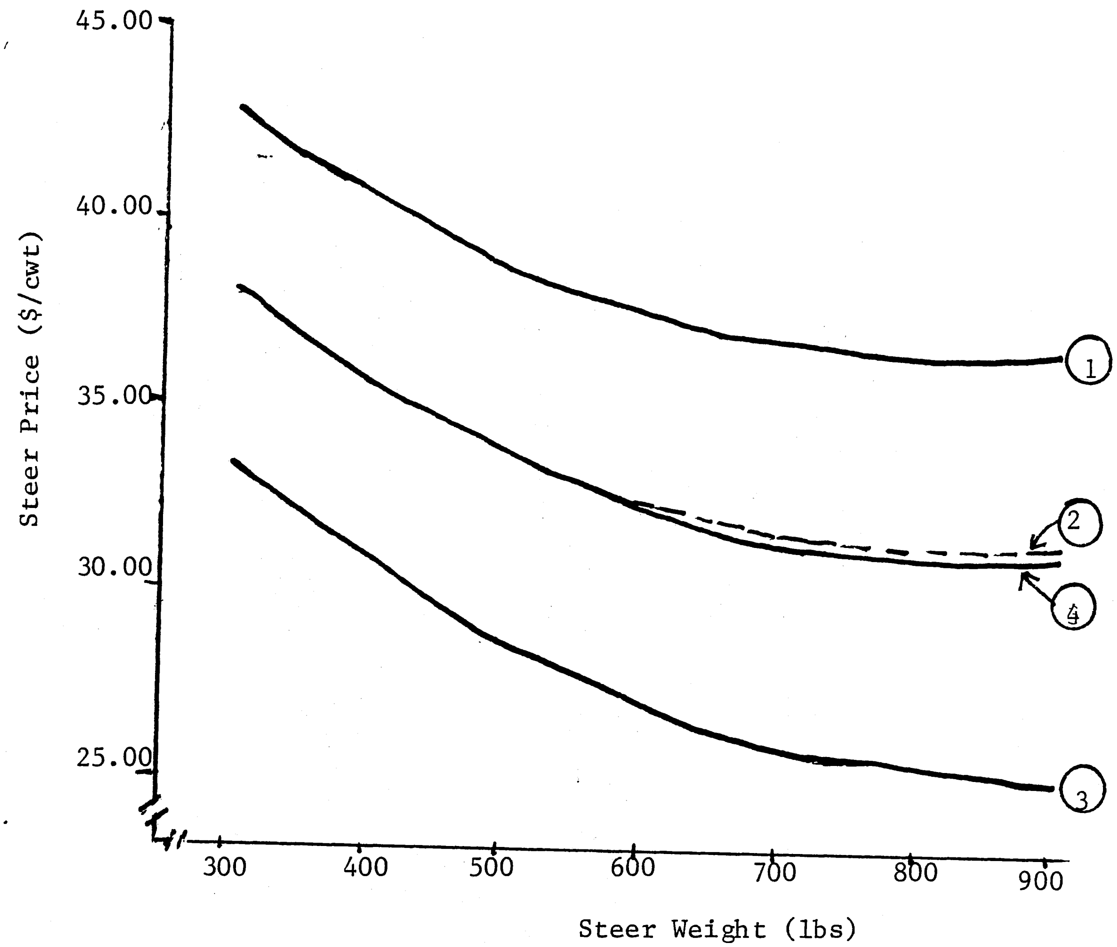
ration-weight interaction variable was included. The interaction variable was formed as the product of ration cost times weight.

Detrending feeder steer and ration prices removes the effects of inflation and allow the cyclical variation to be readily observed. By fixing time trend variables at January, 1969 levels, ration prices are "detrended" and the cycle dominates. Detrending feeder steer prices by fixing the time trend variables at January, 1969 levels, the 600 lbs. feeder steer prices varies from a peak of $52.54 to a bottom of $43.65 (Figure 3-19). The feeder steer price cycle estimations "lead" the ration price with the steer price cycle "peaking" six months prior to the ration price. Greater oscillations are observed for ration prices than for feeder steer prices. This is more cyclical variation than might have been expected, but the parameters for the sine and cosine variable are very strong. Assuming feed grain production is not influenced by cattle production, Figure 3-19 may indicate that producers are willing to purchase more grain during peak cattle price years than in low cattle price years thus the feed grain prices are "bid up" as cattle prices peak.

The typical feeder steer weight-price relationship indicates that prices are "bid up" for more efficient light weight feeders and discounted for less efficient heavier feeders. At different points in the price cycle the discounting of heavier feeders is generally similar, but some differences do appear. At the peak of the cattle price cycle, heavier feeder steers tend to not be discounted as much and the weight-price relationship flattens. This is the case since ration prices tend to peak close to when feeder cattle prices peak. According to the parameter of the feeder steer price equation, high ration cost led to less discounting of heavier steers. This is intuitively logical since high feed cost makes grass feeding of light animals more competitive, hence light animals are not in demand by feedlots when ration prices are high. Similarly at the midpoint of the down phase of the price cycle, high ration prices continue to lessen the discounting of heavy steers. At the bottom of the feeder price cycle, heavy feeder steers are discounted as ration prices are low and cycle variables discount the feeder price. Low ration prices continue to discount heavy steer prices through the midpoint of the upphase of the cycle; however, the weight-price relationship again begins to flatten (Figure 3-20).

When observing the R^2 of the estimated price equation, there was continual improvement with cycle length increasing up to 12 years, and very slight improvement from 12-15 years with the R^2 peaking at 15 years. A 15-year cycle was considered characteristic of the 1958-1979 data period although not necessarily a longrun characteristic. Literature reflecting price estimations made over longer data periods strongly indicated a 12-year cycle and were less likely to pick up "noise" that would be reflected by a shorter data period. Because the R^2 leveled off with the 12-year cycle and because the literature made a definite case of the 12-year cycle, estimates including a 12-year cycle were chosen.

The price estimates reported above were used in valuing the classes cattle considered in the model. The stocker price (SPRICE) subroutine uses the estimated equations to assign a daily price to each stocker weight. Prices are determined for the midpoint of each five-pound stocker steer category from 350-950 pounds. These prices



Legend:
1 -- Cycle Values Are Set at the Peak of the Feeder Cattle Price Cycle
2 -- Cycle Values Are Set For the Midpoint of the Downphase of the Feeder Cattle Price Cycle
3 -- Cycle Values Are Set at the Bottom of the Feeder Cattle Price Cycle
4 -- Cycle Values Are Set at the Midpoint of the Uppphase of the Feeder Cattle Price Cycle

Figure 3-20. Feeder Steer Weight-Price Relationships at Different Points in the Cattle Price Cycle are then used in the steer-heifer price spread equation to determine heifer price for each five-pound weight group of heifers weighing from 350-850 pounds. Heifer prices also reflect the midpoint of each five-pound weight group.

Following King's research, the 821 lb. good heifer price serves as a proxy for comparing a stocker heifer's value to that of a brood cow. Young brood cows are expected to be more valuable than aged cows, hence King developed a discounting procedure to compensate between the value of a good 821 lb. heifer price and the estimated cull price for older cows. The cull cow price for each age of cow is in essence determined by interpolating between the price for a good heifer and the price for cull cows. Cows above the age of nine are assumed to sell for the cull cow price, while cows between the age of two and nine sell at some price between the price for good heifers and the price for cull cows. This price is determined by linear interpolation between the two prices. Table 3-1, column 9 shows the linear interpolation weights used.

The SPRICE subroutine also assigns a per head weaning value to each stocker and replacement heifer. To record changes in value as they grow, the stocker weaning values are converted to flows in the stocker value subroutine (STKVAL) and then sent to VDEL. In VDEL, the weaning value flows are moved through the cascaded delays in a distribution identical to the stocker flows. This allows a record of the weaning value to accompany each stocker. This weaning value can then be compared with the current value of the stocker and costs of raising the stocker since weaning to see if the stocker is making a profit. As a brood cow's value is largely determined by the worth of the calf she will wean, the SPRICE subroutine assigned an expected (TH) calf weaning value to each cow.

In addition to individually valued production, the model keeps a yearly record of herd value, stocker steer sales, stocker heifer sales, and cull sales.

Summary

In summary, the model: (1) utilizes a continuous variable length delay for distributing growth, costs, and values of stockers; (2) utilizes discrete delays for aging cows and replacements and culling cows; (3) calculates fixed and variable costs for stockers, replacements, and brood cows on a per head and cumulative basis; and (4) estimates daily values of brood cows, replacements, and stockers.

Specifically, cows are bred in June for March calving. Average calf weaning weights and successful calving rates are associated with each cow's age. Calving dates occur between February 15th and April 15th with a unique weaning weight premium or discount associated with each calving date. Calving dates combined with the cow herd age structure determine the weaned feeder calf weights. Feeder calves are then sold at weaning or held as stockers. Stockers "grow" by moving through cascaded 50-pound continues variable length delays. Monthly growth rates and maintenance costs are associated with each 50-pound increment of stockers. The continuous variable length delay distributes the growth of stockers to allow for superior or inferior performance. Cumulative maintenance costs and sales value remains attached to the growing stocker.

Cows are culled upon reaching 16 years of age (weaning 15 calves), reaching a management determined age, or failing to wean two calves. Cull cow values are related to the 800-lb. heifer value. Records of the average value of a calf that a cow is carrying, the cow's cumulative yearly and lifetime costs, and the cow's daily costs are also reported. Variable and fixed costs are charged to all animals held on the ranch with the low point on the per head (cow-equivalent) average total cost curve occurring when 100-head of cow-equivalent units are present on the ranch.

CHAPTER IV

MODEL SIMULATION AND ANALYSIS OF THE RESULTS

The first application of the model is to develop two baseline cases. These baseline cases are used as a standard of comparison for other management strategies to be developed and tested. They also serve to validate the model. The baseline applications will be reviewed to determine if the model is functioning properly and if the results are consistent with the logic of the structure specified.

The first baseline application is for a 100-head cowherd which sells all calves at weaning. A 100-head herd base will be used for ease of computation and is specified as the least cost per head herd size. The second baseline is for a mixed cow-calf-stocker operation. In determining this baseline case, the most profitable mixture of brood cows and retained stockers is sought. To keep the baseline case simple, the mixture of brood cows and stockers is held constant over the cycle. Later strategies attempt to determine if varying the brood cow/stocker ratio at various points in the cattle price cycle is desirable. This baseline case also attempts to determine the length of time or weight to which stockers should be held.

The baseline cases utilizes costs, forage availability, and output prices to determine net profits for a constant herd size. As discussed in Chapter Three, cyclical price equations are used to generate cyclical cattle prices and supplemental feed prices through time. The cyclical input and output prices resulted in cyclical profits.

To further emphasize the effects of the price cycle, price trends were frozen at 1969 values (the mid-point of the price data series). Fixing the trend values allow the cyclical prices to oscillate around a constant value. Thus, all impacts of cyclical prices on costs and returns continue to occur. This also establishes the average profit level over a cycle since the input/output price ratio is set. It is contended that holding the input/output price ratio constant is consistent with an assumption of constant technology. To elaborate, it is contended that the input/output price spread will narrow over time due to technological improvements. Holding the spread constant, therefore, assumes constant technology.

To make valid comparisons between various baseline strategies and other management strategies, it was necessary to determine the equilibrium or stable repetitive pattern generated by any proposed strategy. Because cow productivity changes by age and because cows are retained in the herd from four to perhaps 15 years, the effects of any particular culling and replacement pattern will not stabilize for some 30 to 40 years. For example, consider the first baseline strategy. In this strategy, a constant herd size is desired. All cows over the age of eight are culled as well as any cow that looses more than one calf. The replacement strategy is then to replace all culls and deaths that occurred during a year so as to maintain a constant herdsize. The model was initialized with a 100-head cow herd. The age distribution of the 100 cows was arbitrarily specified as uniform over ages two through eight. As this strategy is executed over time, the age distribution of the herd changes. In fact, it tends to change to a declining distribution with the largest number of cows being two-year-old replacement heifers. Older age groups have fewer numbers of cows due to performance culling and deaths, assuming replacements are always two-year-old cows.

Anywhere from 30 to as many as 80 years are required for the cowherd age distribution to stabilize under various strategies. As long as the age distribution is changing from year to year or cycle to cycle, the performance measures of the model, such as total revenue from sales, will not be stable. This is because cow productivity is a function of age. Hence, before the results of any strategy can be objectively reported for comparison with another strategy, a stable herd age distribution and size (or pattern for the case of variable herd size strategies) has to be established. This proves to be a significant task when constant herd size is desired. The slightest inconsistency in culling and replacement interfacing results in continually growing or continually shrinking herd sizes.

The same basic problem of long-run herd growth or contraction also exists for variable herd size strategies. In this strategy, the herd size is allowed to vary over a cycle, but long-run stability in the average size of the herd is desired over a complete cycle. Hence, long-run culling and replacement activities have to be exactly in balance for stable, repetitive patterns to be generated.

Strategy 1--Constant Herd Size/Sell at Weaning

This strategy consists of a set of culling and replacement decisions designed to hold the herd at a constant size of 100-head of cows. Calves will always be sold at weaning in October, hence no stocker operation will be considered. A fixed culling age of nine years of age, or eight calving years was selected. Previous studies have shown this to be a reasonable culling age. Hence total culls consist of all cows which have produced eight calves plus other cows that have failed to wean a calf for the second time. As previously discussed, animal science data indicates that approximately 20 percent of all cows failing to wean a calf in a given year are repeat failure cases.

In order to maintain a constant herd size of 100 cows, adequate replacements must be held from the weaned heifer "crop" one year in advance. Adequate replacements include: a) enough heifers to replace all cows that are culled because of age or second time weaning failure; b) cows that die; and c) replacement heifers that die before entering the cow herd. In reality, and in a modeling sense, this is not an easy task since it implies that events happening one year into the future must be anticipated to retain the correct number of replacement heifers. The biggest problem, even from a modeling viewpoint, is anticipating the number of cow deaths and cullings due to weaning performance. Death rates and weaning rates are both a function of cow age. Until a stable equilibrium herd situation is obtained, the age structure of the breeding herd, and hence the deaths and weaning failures, will change from year to year. Once an equilibrium situation is reached, the age structure of the herd will stabilize and the same number of replacement heifers will be needed each year. However, this number can not be known in advance and must be solved for by simulation.

To solve for the equilibrium age distribution and replacement rate, the cowage distribution was initialized as a uniform distribution. Projections of needed replacements were then made one year into the future and the required replacements withheld to keep a stable 100-head cowherd. This process was repeated for approximately 80 years before the age distribution and replacement rate became stable.

The stable/equilibrium structure found for the constant herd size/sell at weaning model is shown in Table 4-1. For a 100-head cowherd, 14.2935 replacements are needed each year. Before having their first calf, 0.2493 of the heifers die. Hence the number of cows in the herd which have had one calf becomes 14.0442 or 14.2935-0.2493. When looking at the cowherd age structure, cow numbers decline as the cows increase in age. In aging from the first to the eighth calf, the initial 14.0442 cows entering the herd will attrition to 10.9635 cows. This attrition is due to death and culling after the loss of two calves and totals approximately 3.1 cows. Upon weaning the eighth calf, the 10.9635 cows remaining will then be culled due to age. When the herd has achieved an equilibrium condition, a net loss of 14.2935 cows will occur each year and must be replaced.

Table 4-2 explains the annual summaries of returns and costs over a 12-year price cycle for the constant herd size/sell at weaning strategy. Column #1 gives the sum of the annual variable and fixed

TABLE 4 - 1

THE NUMBER OF COWS, STOCKERS AND REPLACEMENT HEIFERS IN THE CONSTANT HERD STRATEGY MODELS AT THE BEGINNING OF THE FISCAL YEAR (OCTOBER 1)[1]

Cow Age by Number of Calves	Strategy 1	Strategy 2
1	14.0442	8.0052
2	13.7304	7.8263
3	13.1217	7.4794
4	12.7166	7.2485
5	12.3882	7.0613
6	11.5920	6.6074
7	11.4434	6.5227
8	10.9635	6.2492
Total number of cows	100.0000	57.0000
Total number of replacement heifers	14.2935	8.1473
Total number of stockers	0.0000	43.1261
Total number of animals	114.2935	108.2734

[1]When the herd reaches a stable "equilibrium" state, the herd is characterized by a declining age structure due to culling of reproductive failures and animal death.

TABLE 4 - 2

ANNUAL COSTS AND RETURNS OVER A 12 YEAR PRICE CYCLE FOR BASE STRATEGY 1: 100 HEAD COW HERD/SELL CALVES AT WEANING, CULL COWS UPON WEANING THE EIGHTH CALF OR UPON SECOND REPRODUCTIVE FAILURE

Annual Summary of Total Costs and Income ($)

Year	Brood Cow Maintenance Costs	Replacement Maintenance Costs	Stocker Steer Maintenance Costs	Stocker Heifer Maintenance Costs	Stocker Steer Revenue	Stocker Heifer Revenue	Cull Cow Revenue	Market Value of Steers at Weaning	Market Value of Heifers at Weaning	Net Profit
1*	9801.88	1141.43	0.00	0.00	7707.43	4274.46	2554.67	7707.42	4274.46	3593.24
2	9902.41	1153.26	0.00	0.00	7556.31	4218.34	2455.09	7556.30	4218.34	3174.06
3	10041.91	1164.55	0.00	0.00	7194.93	4031.96	2320.32	7194.92	4031.96	2340.75
4	9968.33	1164.64	0.00	0.00	6719.16	3770.35	2178.23	6719.15	3770.35	1534.77
5	9913.87	1162.03	0.00	0.00	6258.94	3499.16	2075.73	6258.93	3499.16	757.91
6	9826.77	1147.94	0.00	0.00	5934.47	3300.58	2023.70	5934.46	3300.58	284.04
7	9715.48	1134.03	0.00	0.00	5838.01	3220.15	2052.65	5838.01	3220.15	261.30
8	9622.57	1116.97	0.00	0.00	5989.98	3285.36	2139.65	5989.97	3285.36	675.44
9	9550.65	1112.99	0.00	0.00	6354.40	3465.28	2287.95	6354.40	3465.28	1443.99
10	9545.23	1109.16	0.00	0.00	6824.58	3725.60	2425.23	6824.57	3725.60	2321.03
11	9611.35	1111.72	0.00	0.00	7289.80	4001.90	2525.42	7289.79	4001.90	3094.05
12	9688.83	1129.62	0.00	0.00	7615.90	4193.88	2589.49	7615.89	4193.87	3580.82
Net Profit over the 12 year price cycle										$23,061.40

*Year 1 is the peak of the 12 year price cycle.

costs attributed to the cow herd for each year of the price cycle. As discussed in Chapter Three, cow herd costs include variable costs of labor, supplemental feed, forage replacement (bermuda hay) when forage is lacking, taxes, veterinary care, handling, other variable costs and fixed costs. Replacement costs (column #2) contain the same costs, but for replacement heifers that are being held in the replacement pool. As no stockers are present on the ranch, no costs are changed to stocker steers (column #3) or stocker heifers (column #4). Costs associated with calves prior to weaning are included in the cow herd costs and charged to the brood cows. Had stockers been present on the ranch, variable and fixed costs would have been charged to the stockers and the stockers would have served to "spread" the fixed costs across brood-cows, replacements, and stockers. Columns #5 and #6 give the total annual gross revenue from steer sales and heifer sales. Gross revenue from sales of cows that were culled for performance failures (calving failures) and age is summarized for each year in column #7. To show the increase in feeder cattle values by holding stockers, the stocker weaning values are summarized. Columns #8 and #9 summarize the total weaned sales value of the steers and heifers raised on the ranch had the calves been sold at weaning. Net returns over weaned value from holding stockers can be determined by the difference between the stocker gross revenue (columns #5 and #6), the calves weaning value (columns #8 and #9), and the stocker costs inferred in attaining the gains in value (columns #3 and #4). As the calves are sold at weaning in this case, the stocker gross revenue from sales and the stocker weaned value are equal. Net profits for the ranch (column #10) are calculated as the difference between gross revenue from stockers (columns #5 and #6) and culls cows (column 7) and the costs inferred by the ranch from the cow herd (column #1), the replacement herd (column #2), and the stockers (columns #3 and #4).

Strategy 1 generates cyclical returns for the firm with positive net returns above fixed and variable costs indicated for every year (Table 4-2). At first consideration, these profits may appear to be higher than expected for the beef industry (i.e. at the bottom on the price cycle one might expect to see losses). However, division of the net profit figure by 100 indicates returns per cow varied from a high of $35.80 per cow to a low of $2.61. Average return per cow over the cycle was $19.22 which is 11.7 percent of the average value of a cow over the cycle. This 11.7 percent return must not only cover the opportunity cost of the capital invested in the cow, but also the cost of capital invested in other fixed assets.

Returns above variable costs, Table 4-3, show similar results with an average return of $66.41 per cow per year or 40 percent of the average value of the cow.

Returns from a two-year-old heifer entering the cow herd at various points of the cycle were considered (Table 4-4). Highest net returns of $372.73 per head were from two-year-old heifers entering the herd midway during the upphase of the price cycle. Lowest net returns of $241.33 were from two year old heifers entering the herd at the peak of the price cycle. The amount of time between these two placement options is only three years, but the change in profit is $141.40 or nearly a 60 percent improvement.

The greater net return earned by a two-year-old heifer entering the herd midway through the upphase of the price cycle is associated

TABLE 4 - 3

ANNUAL COSTS AND RETURNS OVER A 12 YEAR PRICE CYCLE. BASE STRATEGY 1:100 HEAD COW HERD/SELL CALVES AT WEANING*, CULL COWS UPON WEANING THE EIGHTH CALF OR UPON SECOND REPRODUCTIVE FAILURE--RETURNS ABOVE VARIABLE COSTS

Annual Summary of Total Costs and Income ($)

Year	Brood Cow Maintenance Costs	Replacement Maintenance Costs	Stocker Steer Maintenance Costs	Stocker Heifer Maintenance Costs	Stocker Steer Revenue	Stocker Heifer Revenue	Cull Cow Revenue	Market Value of Steers at Weaning	Market Value of Heifers at Weaning	Net Profit
1*	5674.34	553.01	0.00	0.00	7707.43	4274.46	2554.67	7707.42	4274.46	8309.20
2	5774.10	565.61	0.00	0.00	7556.31	4218.34	2455.09	7556.30	4218.34	7890.02
3	5874.76	576.44	0.00	0.00	7194.93	4031.96	2320.32	7194.92	4031.96	7096.01
4	5840.54	576.47	0.00	0.00	6719.16	3770.35	2178.23	6719.15	3770.35	6250.73
5	5787.72	572.23	0.00	0.00	6258.94	3499.16	2075.73	6258.93	3499.16	5473.87
6	5699.32	559.43	0.00	0.00	5934.47	3300.58	2023.70	5934.46	3300.58	5000.00
7	5588.33	545.22	0.00	0.00	5838.01	3220.15	2052.65	5838.01	3220.15	4977.25
8	5493.45	530.14	0.00	0.00	5989.98	3285.36	2139.65	5989.97	3285.36	5391.39
9	5424.18	523.51	0.00	0.00	6354.40	3465.28	2287.95	6354.40	3465.28	6159.94
10	5417.67	520.75	0.00	0.00	6824.58	3725.60	2425.23	6824.57	3725.60	7036.98
11	5481.68	525.44	0.00	0.00	7289.80	4001.90	2525.42	7289.79	4001.90	7810.00
12	5562.65	539.84	0.00	0.00	7615.90	4193.88	2589.49	7615.89	4193.57	8296.77
Net profit over the 12 year price cycle										$79,692.12

*Year 1 is the peak of the price cycle

TABLE 4 - 4

GROSS RETURNS AND NET PROFITS PER YEAR OVER AN EIGHT YEAR CALVING HORIZON FROM A TWO YEAR OLD COW ENTERING THE COW HERD AND WEANING THE FIRST CALF AT DIFFERENT POINTS IN THE PRICE CYCLE. THE RETURNS WERE YIELDED UNDER THE CONSTANT HERD SIZE/SELL CALVES AT WEANING STRATEGY

	A Two Year Old Heifer Entering the Herd and Weaning Her First Calf at the Following Points in the Cycle							
	Peak of Price Cycle		Mid-Drop of Price Cycle		Bottom of Cycle		Mid-Rise of Cycle	
Cow Age by # of Calves	Calf Weaning Value	Net Profit	Calf Weaning Value	Net Profit	Calf Weaning Value	Net Profit	Calf Weaning Value	Net Profit
1	147.70	49.11	129.96	29.41	112.70	12.04	130.44	32.91
2	145.22	46.93	124.30	23.30	117.95	18.21	143.02	46.06
3	146.71	47.31	120.65	19.53	128.01	29.39	154.08	57.21
4	141.03	40.48	121.20	20.54	141.58	44.05	161.40	63.93
5	131.01	30.02	124.03	24.30	151.59	54.63	158.57	60.31
6	123.76	22.64	131.49	32.87	158.84	61.97	151.11	51.71
7	121.70	20.54	141.58	44.05	161.40	63.93	141.03	40.61
8	124.03	24.30	151.59	54.63	158.57	60.13	131.01	29.99
Total	1080.66	241.33	1044.78	249.63	1130.64	344.53	1170.66	382.73

with several factors. First, she will be in the herd during the six highest priced years of the price cycle. Secondly, and perhaps just as important, her calving productivity peaks close to the peak of the price cycle. Calving productivity data reported in Chapter Three indicates that brood cows peak in successful rates of weaned calves and weight of weaned calves for their fourth, fifth and sixth calves. Hence cows entering the head midway through the upphase of the price cycle will reach peak productivity during the three years following the price peak.

Figure 4-1 shows the gross and net returns earning patterns reported in Table 4-4. The figures point out that the cycle affects not only the level of earnings of a cow over her productive life, but the pattern also. A heifer placed at the peak of the cycle (curve #1) experiences continual declines in earnings. Earnings do not decline as rapidly in the first three years because rising calving productivity tends to offset falling prices. Prices bottom as this cow produces her seventh calf, hence revenue picks up slightly for the eighth calf. By contrast a heifer placed in the herd at the bottom of the price cycle (curve #3) experiences rising earning throughout her lifetime until the eighth calf. During this cow's first four calving years prices as well as her calving productivity are rising, thus earnings increase rapidly. The price cycle peaks as she produces her seventh calf and as a result earnings on the eighth calf drop. Of the four placement years considered in the graph, curve #4, depicting placement at the midpoint of the upphase of the price cycle, generates the greatest total profit. Profits with this placement year rise over the first four calves and fall for the last four. However, profits

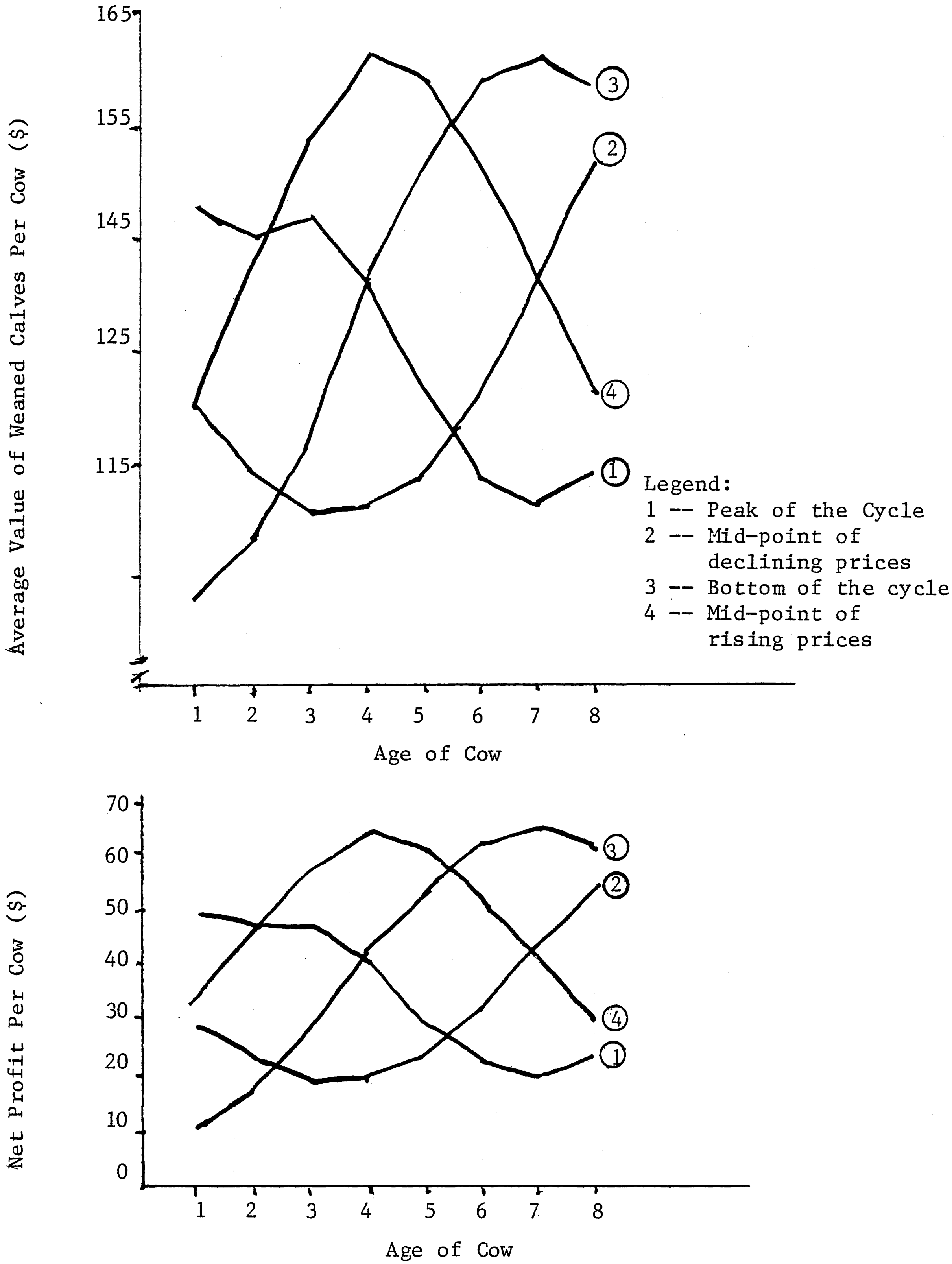


Figure 4-1. Returns From a Two Year Old Cow Entering the Herd (Weaning the First Calf) as Different Points in the Cycle

remain relatively high for all but the first and last calf produced. The fourth placement year alternative displayed in the figure is to place a heifer in the herd halfway through the down phase of the price cycle. This placement date meets with relatively unfavorable results because prices are relatively low during the cows most productive years. When prices do start to rise, the cow experiences declining calving productivity which reduces profits.

The proceeding four cases were analyzed and reported to develop an understanding of how the price cycle and the cow calving productivity interact to affect net returns. None of the four placement periods selected is actually the best of the 12 possible years. Table 4-5 presents the gross and net revenues earned by heifers placed in the herd during each of the twelve years of the cycle. Highest returns were generated for the heifers that were placed in year nine of the cycle which is two years after the bottom of the 12-year price cycle. A heifer placed in year nine yields rapidly increasing returns during her first five calving years as prices as well as her calving productivity rise. Returns drop over the last three calving years as prices begin the down phase of the price cycle; however, the cows productivity and slowly declining prices serve to keep gross returns relatively high for the last three calves. Net returns are relatively high for all but the first year. Net returns of \$388.15 are \$146.82 higher for heifers held in year nine than for the heifers placed at the peak of the cycle, i.e. year one, which yield the lowest net returns of \$241.33.

Lowest gross returns are from heifers placed in year three as the calving periods coincide with the down phase and bottom of the price

TABLE 4 - 5

GROSS RETURNS AND NET PROFITS PER YEAR FOR A TWO YEAR OLD COW ENTERING THE HERD AND WEANING THE FIRST CALF AT DIFFERENT POINTS IN THE 12 YEAR PRICE CYCLE. THE RETURNS WERE YIELDED UNDER THE CONSTANT HERD SIZE/CALVES SOLD AT WEANING STRATEGY

	Gross Returns ($) A Two Year Old Heifer Entering the Cow Herd in Year:											
No. of calves Weaned	1	2	3	4	5	6	7	8	9	10	11	12
1	147.70	145.24	138.74	129.96	121.24	114.92	112.70	115.16	121.66	130.44	139.16	145.48
2	145.22	142.58	133.41	124.30	117.70	115.37	117.95	124.73	133.91	143.02	149.62	151.94
3	146.71	137.10	127.56	120.65	118.21	120.91	128.01	137.62	147.16	154.08	156.51	153.81
4	141.03	131.01	123.76	121.20	124.03	131.49	141.58	151.59	158.84	161.40	158.57	151.11
5	131.01	123.76	121.20	124.03	131.49	141.58	151.59	158.84	161.40	158.57	151.11	141.03
6	123.76	121.70	124.03	131.49	141.58	151.59	158.84	161.40	158.57	151.11	141.03	131.01
7	121.70	124.03	131.49	141.58	151.59	158.84	161.40	158.57	151.11	141.30	131.01	123.76
8	124.30	131.49	141.58	151.59	158.84	161.40	158.57	151.11	141.03	131.01	123.76	123.76
Total Gross Returns Over The Cycle	1080.66	1056.91	1041.77	1044.78	1064.68	1096.10	1130.64	1159.02	1173.68	1170.66	1150.77	1121.90
	Net Returns ($)											
1	49.11	42.47	39.34	29.41	19.80	13.81	12.04	15.48	23.04	32.91	41.67	48.61
2	46.93	43.71	32.86	23.30	16.25	14.71	18.21	27.11	36.38	46.06	53.96	54.47
3	47.31	37.04	26.56	19.53	17.72	21.17	29.39	40.48	50.20	57.21	55.48	55.56
4	40.48	30.02	22.64	20.54	24.30	32.84	44.05	54.63	61.97	63.93	60.31	51.71
5	30.02	22.64	20.54	24.30	32.87	44.05	54.63	61.97	63.93	60.31	51.71	40.61
6	22.64	20.54	24.30	32.87	44.05	54.63	61.97	63.93	60.31	51.71	40.61	29.99
7	20.54	24.30	32.87	44.05	54.63	61.97	63.93	60.31	51.71	40.61	29.99	22.66
8	24.30	32.87	44.05	54.63	61.97	63.93	60.31	51.71	40.61	29.99	22.66	23.63
Total Net Returns Over the Cycle	241.33	253.59	243.16	249.63	271.59	307.14	344.53	375.62	388.15	382.73	356.39	327.24

cycle. However, as input feed prices also bottom, the net returns from heifers placed in year three are greater than the net returns from heifers placed at the peak of the cycle.

Strategy 2--Constant Herd Size/Stockers Sold in July

The second baseline strategy incorporates grassfed stockers into a cow-calf herd. The primary decision to be considered is the optimal mix of cows and stockers. Through simulation experiments with the model it was determined that the best mix of cows and stockers was a combination of approximately 57 cows and 43 stockers, with the stockers held for sale in July. This mixture and sales date was not initially obvious from the cost and revenue data. When using a mixed cow-calf-stocker strategy, the optimal herd size is dependent on the mixture of animals on the ranch as well as the date stockers are sold. The longer stockers are held on the ranch, the more pasture forage they consume, hence fewer stockers and/or fewer cows can be held as stockers are retained longer.

It is intuitively obvious that as stockers are held back, the grass pressure increases until it is no longer profitable to hold 100 cows; thus, the cowherd needs to be reduced in size to compensate for stockers. The question then is to determine the number of cows and replacements to be held in the herd so that when stockers are added to the herd, the cost level for the herd is maintained at or near its low point on the average total cost curve.

The first step taken in determining the optimal cow-calf-stocker mix and stocker sales date was to determine the best stocker sales date. At first, the stockers were allowed to grow until they reached fat cattle weights and were sold as fat cattle regardless of grass pressure and herd costs. However, due to low growth rates associated with minimally supplemented native grass pasture and variations in the productivity of individual animals, this scenario was deemed inappropriate. The next scenario considered was to sell steers at 800.0 lbs. and heifers at 700.0 lbs. Again, low growth rates associated with native grass pasture eliminated this strategy.

The decision was then made to hold all stockers for sale on the same date regardless of weight, sex or grade. Various sale dates between March and August were considered. Low productivity due to low growth rates in fall, winter, and early spring months eliminated March, April and May as primary sales months because costs in attaining additional gains from the stockers offset the gains in value incurred.

Given the above, the analysis to determine the optimal herd size and mix was concentrated on scenarios with stocker sales in June, July and August which took advantage of late spring and summer growth rates. It was expected that the cowherd would need to be reduced to 50 to 70 percent of its normal size when stockers are incorporated. The analysis concentrated the herd size between 50 and 60 percent of the herd size of a sell at weaning strategy. In forcing the cowherd per head costs to costs that are similar to those incurred by the 100-head cow herd constant herd size/sell at weaning strategy, contributions attributed to stockers are forced to be similar to contributions by cows. Since a stable constant herd structure for a 100-head cow herd had been developed, the age distribution of brood cows in the herd for the stable herd was used in developing the second strategy. For example, when a herd of 70 cows was desirable, the initial herd age distribution and replacement rates were adjusted to 70 percent of the values for the 100-head stable herd size. After testing cowherd sizes between 50 and 70 cows for stocker sales strategies, it was determined that 59 cows were optimal for June sales, 57 cows for July sales, and 52 cows for August sales with highest returns yielded in June and July. For June sales, stable conditions indicated 59.0 cows, 8.4332 replacement heifers, and 44.5702 stockers. For July sales, the stable conditions indicated 57.0 cows, 8.1473 replacement heifers, and 43.1261 stockers. Net profits over the cycle for both June and July were comparable with net losses of just over $7,000 in both cases. For August sales, the stable conditions indicated 52.0 cows, 7.4326 replacement heifers and 39.53 stockers. Net profits over the cycle resulted in net losses of approximately $10,000. As June and July returns were comparable, the July 1 midpoint was selected as the stocker sales date for strategy 2.

Annual cost and revenue data for Strategy 2 (57 cows/43.1 stockers sold July 1) are reported in Table 4-6. Strategy 2 generated cyclical returns with positive net returns generated in only four of the twelve cycle years. These four years include the peak year of the cycle and the three years preceeding it. Overall returns for Strategy 2 were a negative $7,374.98. This is in sharp contrast to the positive $23,061.40 of net returns generated under Strategy 1. The difference is due to the unprofitableness of stockers and the foregone income from the 43 cows given up to raise the 43.1 unprofitable stockers.

TABLE 4 - 6

ANNUAL COSTS AND RETURNS OVER A 12 YEAR PRICE CYCLE. BASE STRATEGY 2: 57 HEAD COW HERD
HOLD ALL CALVES AS GRASSFED STOCKERS FOR SALE IN JULY; CULL COWS UPON WEANING
THE EIGHTH CALF OR UPON SECOND REPRODUCTIVE FAILURE

Annual Summary of Total Costs and Income ($)

Year	Brood Cow Maintenance Costs	Replacement Maintenance Costs	Stocker Steer Maintenance Costs	Stocker Heifer Maintenance Costs	Stocker Steer Revenue	Stocker Heifer Revenue	Cull Cow Revenue	Market Value of Steers at Weaning	Market Value of Heifers at Weaning	Net Profit
1*	5585.86	692.95	1608.35	1084.33	5115.87	2839.33	1456.11	4393.08	2436.36	439.82
2	5642.62	699.57	1630.13	1099.53	4893.71	2730.92	1399.35	4306.95	2404.37	-47.88
3	5723.76	704.36	1659.91	1119.18	5474.89	2556.93	1322.54	4100.96	2298.14	-752.85
4	5681.37	706.17	1647.13	1110.32	4236.09	2363.01	1241.55	3829.78	2149.02	-1304.34
5	5652.13	704.94	1636.10	1102.91	3977.85	2202.65	1183.12	3567.46	1994.44	-1734.46
6	5602.04	696.79	1618.81	1091.13	3864.33	2123.15	1153.47	3382.52	1881.26	-1867.83
7	5538.99	688.88	1595.94	1075.94	3929.39	2141.02	1169.97	3327.54	1835.41	-1659.38
8	5484.73	678.91	1574.11	1063.21	4152.05	255.47	1219.55	3414.15	1872.58	-1173.91
9	5446.07	676.99	1560.74	1052.37	4475.92	2426.60	1304.08	3621.87	1975.13	-529.58
10	5442.86	674.74	1557.00	1050.50	4807.84	2618.07	1382.33	389.85	2123.51	83.13
11	5474.54	675.65	1566.61	1058.69	5069.70	2782.37	1439.44	4155.05	2281.01	516.02
12	5521.63	686.30	1586.27	1069.00	5184.37	2857.16	1475.96	4340.92	2390.43	654.28
Net Profit Over the Cycle										-7,374.98

*Year 1 is the peak of the price cycle.

The unprofitability of holding stockers after weaning can be seen by comparing the stocker cost, stocker revenue, and market value at weaning columns in Table 4-6. The stocker steer and heifer costs columns show the cost of holding a stocker steer or heifer from October 1 to July 1. The stocker steer and heifer revenue columns show the revenue earned from sales on July 1, while the market value at weaning columns shows the revenue that could have been earned if the stockers had been sold at weaning. By subtracting the stocker cost column from the stocker revenue column and comparing the results to the weaning value of the animals, the net returns to holding stockers in any year of the cycle can be seen. This has been done and reported in Table 4-7. Table 4-7 shows the returns for each year over a 12-year price cycle for stocker steers and heifers. Stocker steers and heifers yield a net profit over stocker costs each year; however, both stocker steers and heifers yield net losses over their weaned value during all years of the cycle.

When looking at individual animal performance, Table 4-8 shows the returns over a 12-year price cycle for an average steer with the base growth rate. The average steer value ranged from a high of \$202.27 to a low of \$150.77. Net returns over weaned steer value yielded losses ranging from \$24.93 to of \$48.41. The point during the cycle when stockers lose the least amount of money is just prior to the feeder cattle price cycle peak. Net returns for stocker production are primarily affected by the ratio of stocker prices to ration prices. Returns to stocker production are also improved by rising stocker prices from October 1 to July 1. Just prior to the feeder cattle price peak both factors are relatively favorable.

TABLE 4 - 7

STOCKER RETURNS OVER A 12 YEAR PRICE CYCLE UTILIZING THE CONSTANT HERD SIZE/SELL STOCKERS IN JULY STRATEGY[1]

	Total Stocker Steer Returns[2]			Total Stocker Heifer Returns[3]		
Year of the Price Cycle	Steer Sales Revenue ($)	Net Profits Over Steers Costs ($)	Net Profits Over Weaned Value ($)	Heifer Sales Revenue ($)	Net Profit Over Heifer Costs ($)	Net Profits Over Weaned Value ($)
1*	5115.87	3507.52	-885.56	2839.33	1755.00	5681.36
2	4893.71	3263.58	-1043.37	2730.93	1631.39	-772.98
3	4574.98	2914.98	-1185.98	2556.93	1437.75	-860.39
4	4236.09	2588.96	-1240.82	2363.01	1252.69	-896.33
5	3977.85	2339.75	-1227.71	2202.65	1099.74	-894.70
6	3864.33	2245.52	-1137.00	2123.15	1032.02	-849.24
7	3929.39	2333.45	-994.09	2141.02	1065.08	-770.33
8	4152.05	2577.94	-749.60	2255.47	1192.26	-680.32
9	4475.92	2915.18	-706.69	2462.60	1374.23	-600.90
10	4807.84	3250.84	-639.01	2618.07	1567.57	-555.94
11	5069.70	3503.09	-651.96	2782.37	1723.68	-557.33
12	5184.37	3598.10	-742.82	2857.16	1788.16	-602.27
Total Returns Over a 12 Year Cycle	54282.01	35038.91	12247.98	29896.68	16919.57	-8722.09

*Year 1 is the peak of the 12 year price cycle. [1]The stable herd size indicated 57.0 cows, 8.1473 replacements and 43.1261 stockers. [2]25.6367 weaned steers were held as stockers. [3]17.4894 weaned heifers were held as stockers.

TABLE 4 - 8

INDIVIDUAL STOCKER STEER AND HEIFER FROM BASE STRATEGY 2[1] OVER A PRICE CYCLE

	Stocker Steer Returns ($)			Stocker Heifer Returns ($)		
Year of Cycle	Steer Sales Revenue	Net Profit to Steer Costs	Net Profit Over Weaned Value	Heifer Sales Revenue	Net Profit to Heifer Costs	Net Profit Over Weaned Value
1*	199.60	133.49	-34.55	162.34	98.53	-38.95
2	190.93	119.31	-40.70	156.14	87.21	-44.19
3	178.49	103.16	-46.27	146.19	73.69	-49.19
4	165.27	90.78	-48.41	135.11	62.80	-51.24
5	155.20	84.08	-47.90	126.10	56.42	-51.15
6	150.77	91.05	-44.36	121.39	56.40	-48.55
7	153.31	103.97	-38.78	122.41	63.03	-44.04
8	161.99	112.07	-29.24	128.96	74.05	-38.89
9	174.63	124.20	-27.57	138.74	87.07	-34.35
10	187.58	137.24	-24.93	149.69	98.65	-31.78
11	197.80	143.94	-25.43	159.08	104.82	-31.86
12	202.27	142.39	-28.97	163.36	104.88	-34.43
Total Over the Cycle	2117.90	1385.68	-477.87	1709.41	967.55	-498.70

*Year 1 is the peak of the price cycle. [1]Base strategy 2 is the constant herd size (57 cows)/sell stockers in July strategy

Ration prices have not yet turned up as much as feeder prices and feeder prices are rising over the life of the stocker. Just after the peak of the feeder price cycle these conditions reverse themselves. Ration prices continue to rise relative to feeder prices and feeder prices are falling over the life of the stockers, hence stocker net losses increase (Figure 4-2).

Tables 4-6, 4-7 and 4-8 clearly indicate that stocker cattle will not cover their total cost of production. However, Table 4-9 presents the variable cost of production for Strategy 2. Overall returns to Strategy 2 are shown to cover variable costs in all years of the cycle. The best returns are once again just prior to the peak of the cycle. Table 4-10 summarizes the returns above variable costs from the stocker holding activity. Table 4-11 was calculated in a similar manner to Table 4-8; i.e. stocker costs were subtracted from stocker revenues and compared to market value at weaning. As stockers help to "spread" fixed costs for the ranch, returns above variable costs were considered to show the stocker's actual contribution to the ranch. When fixed costs were eliminated positive net profits were yielded for each of the 12 years. Net profits for the ranch peaked one year prior to the peak of the price cycle (Table 4-9). Specifically, stocker steers yielded $45,142.55 positive returns over variable costs with a loss of $1,187.58 over the 12-year cycle when compared to their weaned value. Net returns over weaning were yielded during the five years immediately preceeding the peak of the price cycle. Stocker heifers yielded a positive return of $23,544.69 over variable costs over the price cycle but showed a loss of $2,096.97 when compared to their weaned value. Stocker heifers yielded positive returns over weaning

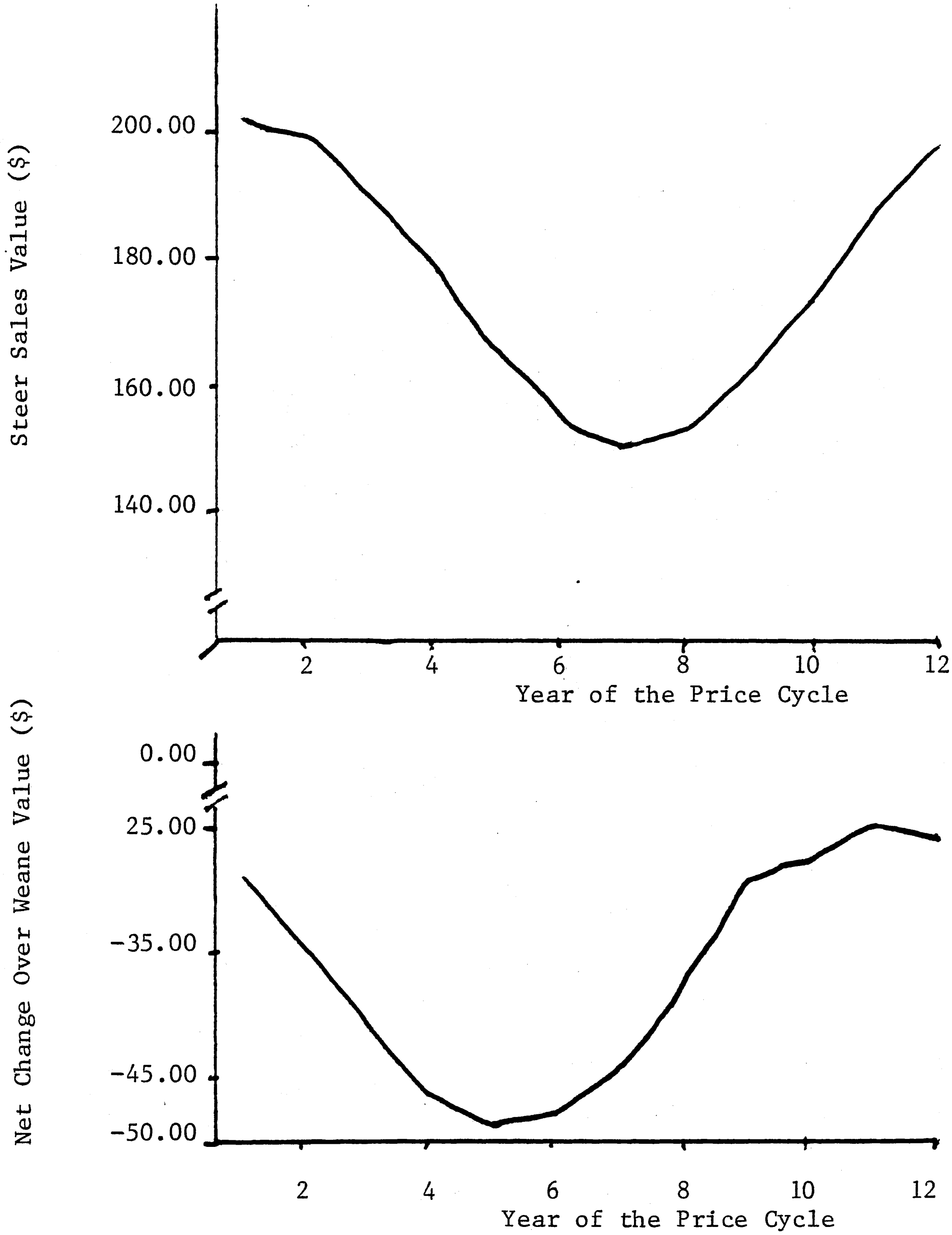


Figure 4-2. Stocker Steer Sales Value Over a 12-Year Price Cycle Assuming the Base Growth Rate and an Average Steer. Year 1 is the Peak of the Cycle

TABLE 4 - 9

ANNUAL COSTS AND RETURNS OVER A 12 YEAR PRICE CYCLE FOR BASE STRATEGY 2: 57 HEAD COW HERD/HOLD ALL CALVES AS GRASSFED STOCKERS FOR SALE IN JULY; CULL COWS UPON WEANING THE EIGHTH CALF OR UPON SECOND REPRODUCTIVE FAILURE --RETURNS ABOVE VARIABLE COSTS

Annual Summary of Total Costs and Income ($)

Year	Brood Cow Maintenance Costs	Replacement Maintenance Costs	Stocker Steer Maintenance Costs	Stocker Heifer Maintenance Costs	Stocker Steer Revenue	Stocker Heifer Revenue	Cull Cow Revenue	Market Value of Steers at Weaning	Market Value of Heifers at Weaning	Net Profit
1*	2693.70	282.23	767.28	512.32	5115.87	2839.33	1456.11	4393.08	2436.36	5155.77
2	2750.38	289.45	789.01	527.05	4893.71	2730.92	1399.35	4306.95	2404.37	4668.07
3	2806.32	295.91	809.29	540.42	4574.89	2556.93	1322.54	4100.96	2298.14	4002.41
4	2789.41	295.67	805.93	538.01	4236.09	2363.01	1241.55	3829.78	2149.02	3411.62
5	2760.88	293.25	796.74	531.25	3977.85	2202.65	1183.12	3567.46	1994.44	2981.50
6	2709.87	285.99	777.75	519.18	3864.33	2123.15	1153.47	3382.52	1881.26	2848.14
7	2647.20	277.91	754.72	503.95	3929.39	2141.02	1169.97	3327.54	1835.41	3056.59
8	2592.02	269.38	733.13	490.48	4152.05	2255.47	1219.55	3414.15	1872.58	3542.06
9	2554.96	265.57	719.28	480.40	4475.92	2426.60	1304.08	3621.87	1975.13	4186.38
10	2550.75	264.04	715.91	478.46	4807.84	2618.07	1382.33	3889.85	2123.51	4799.08
11	2581.54	266.51	725.70	485.77	5069.70	2782.37	1439.44	4155.05	2281.01	5231.98
12	2630.77	274.68	744.72	497.08	5184.37	2857.16	1475.96	4340.92	2390.43	5370.24
Net Profit over the 12 year cycle										$49,253.84

*Year 1 is the peak of the 12 year cycle value for only two years of the cycle and, in those years, returns were minimal (Table 4-10). Table 4-11 shows the individual stockers contribution when fixed costs are eliminated.

Strategy 3--Constant Herd Size = 57/Sell at Weaning

As an academic comparison, strategy 3 was developed to show the contribution of stockers to the ranch. Strategy 3 has a constant herd size of 57.0 cows and 8.1473 replacement heifers with calves sold at weaning, i.e. the same number of cows found to be the most profitable in Strategy 2 but this time no stockers were held. Strategy 3 indicates cyclical returns to the firm with positive net revenues for four years and negative net returns for eight years (Table 4-12). Overall, returns from this strategy were negative. Negative returns resulted because fixed costs were only distributed over 57 animals. Hence, average total costs per brood cow over the cycle in this case verses the 100-head case was $117.80 verses $97.66. Realizing that stockers and cows share fixed costs, returns above variable costs were considered (Table 4-13). Again cyclical returns to the firm were observed, but all net returns were positive.

Comparisons of Strategies 2 and 3

Comparing strategies 2 and 3, including stockers in the cowherd spread fixed costs and lowered total costs for the cowherd. However, variable costs were considerably higher due to low stocker growth associated with native grass pasture that is minimally supplemented

TABLE 4 - 10

STOCKER RETURNS FROM BASE STRATEGY 2[1] OVER A 12-YEAR PRICE CYCLE --RETURNS ABOVE VARIABLE COSTS

	Stocker Steer Returns ($)			Stocker Heifer Returns ($)		
Year of Cycle	Steer Sales Revenue	Net Profit to Steer Costs	Net Profit Over Weaned Value	Heifer Sales Revenue	Net Profit to Heifer Costs	Net Profit Over Weaned Value
1*	5115.87	4348.59	-44.49	2839.33	2327.01	-109.35
2	4893.71	4104.70	-202.25	2730.92	2203.90	-200.47
3	4574.89	3765.60	-335.36	2556.93	2016.50	-281.64
4	4236.09	3430.16	-399.62	2363.01	1825.00	-324.02
5	3977.85	3181.11	-386.35	2202.65	1671.40	-323.04
6	3864.33	3086.58	-295.94	2123.15	1603.97	-277.29
7	3929.39	3174.67	-152.87	2141.02	1637.07	-198.34
8	4152.05	3418.92	4.77	2255.47	1764.99	-107.59
9	4475.92	3756.64	134.77	2426.60	1946.20	-28.93
10	4807.84	4091.93	202.08	2618.07	2139.61	16.10
11	5069.70	4344.00	188.95	2782.37	2296.60	15.59
12	5184.37	4439.65	98.73	2857.16	2112.44	-277.99
Total over the cycle	54,282.01	45,142.55	-1,187.58	29,896.68	23,544.69	-2,096.97

*Year 1 is the peak of the price cycle. [1]Base strategy 2 is the constant herd size (57 cows)/sell stockers in July strategy. This particular case eliminates fixed costs.

TABLE 4 - 11

INDIVIDUAL STOCKER STEER AND HEIFER RETURNS FROM BASE STRATEGY 2[1] OVER A 12 YEAR PRICE CYCLE--RETURNS ABOVE VARIABLE COSTS

	Stocker Steer Returns ($)			Stocker Heifer Returns ($)		
Year of Cycle	Steer Sales Revenue	Net Profit to Steer Costs	Net Profit Over Weaned Value	Heifer Sales Revenue	Net Profit to Heifer	Net Profit Over Weaned Value
1*	199.60	169.66	-1.73	162.34	133.05	-6.25
2	190.93	160.15	-7.89	156.14	126.01	-11.46
3	178.49	146.92	-13.08	146.19	115.30	-16.10
4	165.27	133.83	-15.59	135.11	104.35	-18.52
5	155.20	124.11	-15.07	126.10	95.56	-18.47
6	150.77	120.42	-11.54	121.39	91.71	-15.85
7	153.31	123.86	-5.96	122.41	93.60	-11.34
8	161.99	133.39	0.18	128.96	100.92	-6.15
9	174.63	146.57	5.25	138.74	112.35	-1.65
10	187.58	159.65	7.88	149.69	122.34	0.92
11	197.80	169.48	7.37	159.08	131.31	0.89
12	202.27	173.22	3.85	163.36	120.78	-15.89
Total over the cycle	2,117.84	1,761.26	-46.33	1,709.41	1,387.28	-1,19.87

*Year 1 is the peak of the price cycle. [1]Base strategy 2 is the constant herd size (57 cows)/sell stockers in July strategy. This particular case eliminates fixed costs.

TABLE 4 - 12

ANNUAL COSTS AND RETURNS OVER A 12 YEAR PRICE CYCLE FOR BASE STRATEGY 3: 57 HEAD COW HERD/SELL CALVES AT WEANING, CULL COWS UPON WEANING THE EIGHTH CALF OR REPRODUCTIVE FAILURES

Annual Summary of Total Costs and Income ($)

Year	Brood Cow Maintenance Costs	Replacement Maintenance Costs	Stocker Steer Maintenance Costs	Stocker Heifer Maintenance Costs	Stocker Steer Revenue	Stocker Heifer Revenue	Cull Cow Revenue	Market Value of Steers at Weaning	Market Value of Heifers at Weaning	Net Profit
1*	6732.68	863.12	0.00	0.00	4393.08	2436.36	1456.11	4393.08	2436.36	689.75
2	6790.07	869.58	0.00	0.00	4306.95	2404.37	1399.35	4306.95	2404.37	451.01
3	6884.84	876.49	0.00	0.00	4100.96	2298.14	1322.54	4100.96	2298.14	-39.70
4	6828.64	876.32	0.00	0.00	3829.78	2149.02	1241.55	3829.78	2149.02	-484.61
5	6798.62	875.51	0.00	0.00	3567.46	1994.44	1183.12	3567.46	1994.44	-929.11
6	6748.88	866.99	0.00	0.00	3382.52	1881.26	1153.47	3382.52	1881.26	-1198.63
7	6685.93	859.19	0.00	0.00	3327.54	1835.41	1169.97	3327.54	1835.41	-1212.21
8	6632.61	848.71	0.00	0.00	3414.15	1872.58	1219.55	3414.16	1872.58	-975.04
9	6593.04	847.53	0.00	0.00	3621.87	1975.13	1304.08	3621.87	1975.13	-539.50
10	6589.92	844.93	0.00	0.00	3889.85	2123.51	1382.33	3889.85	2123.51	-39.17
11	6622.46	845.29	0.00	0.00	4155.05	2281.01	1439.44	4155.05	2281.01	407.75
12	6668.37	856.91	0.00	0.00	4340.92	2390.43	1475.96	4340.92	2390.43	682.03
Net Profit over the cycle										-3,187.43

*Year 1 is the peak of the price cycle

TABLE 4 - 13

ANNUAL COSTS AND RETURNS OVER A 12 YEAR PRICE CYCLE FOR BASE STRATEGY 3: 57 COW HERD/SELL CALVES AT WEANING, CULL COWS UPON WEANING THE EIGHTH CALF OR SECOND REPRODUCTIVE FAILURE--RETURNS ABOVE VARIABLE COSTS

Annual Summary of Total Costs and Income ($)

Year	Brood Cow Maintenance Costs	Replacement Maintenance Costs	Stocker Steer Maintenance Costs	Stocker Heifer Maintenance Costs	Stocker Steer Revenue	Stocker Heifer Revenue	Cull Cow Revenue	Market Value of Steers at Weaning	Market Value of Heifers at Weaning	Net Profit
1*	2616.56	263.24	0.00	0.00	4393.08	2436.36	1456.11	4393.08	2436.36	5405.75
2	2673.45	269.70	0.00	0.00	4306.95	2404.37	1399.35	4306.95	2404.37	5167.30
3	2768.72	276.61	0.00	0.00	4100.96	2298.14	1322.54	4100.96	2298.14	4676.30
4	2712.53	276.44	0.00	0.00	3829.78	2149.02	1241.55	3829.78	2149.02	4231.39
5	2632.76	275.63	0.00	0.00	3567.46	1994.44	1183.12	3567.46	1994.44	3786.89
6	2032.88	267.11	0.00	0.00	3382.52	1881.26	1153.47	3382.52	1881.26	3517.37
7	2569.81	259.31	0.00	0.00	3327.54	1835.41	1169.97	3327.54	1835.41	3503.79
8	2516.49	248.83	0.00	0.00	3414.15	1872.58	1219.55	3414.15	1872.58	3740.79
9	2476.92	247.65	0.00	0.00	3621.87	1975.56	1304.08	3621.87	1975.13	4176.50
10	2473.80	245.05	0.00	0.00	3889.85	2123.51	1382.33	3889.85	2123.51	4676.83
11	2506.34	245.41	0.00	0.00	4155.05	2281.01	1439.44	4155.05	2281.01	5123.75
12	1352.49	247.03	0.00	0.00	4340.92	2390.43	1475.96	4340.92	2390.43	5398.03
Net Profit Over the 12 Year Cycle										53,404.75

*Year 1 is the peak of the price cycle

(Table 4-6). As a result, net profits were higher for the sell weaning strategy. Holding stockers over the peak of the price cycle increases net profits for those four years. Thus, a cyclical herd strategy that incorporates stockers into the cowherd over the peak price period may be desirable. This strategy will be examined later.

Comparisons of Strategies 1 and 2

As indicated by Table 4-2 and 4-6, the largest net profits of the three baseline strategies tested were for the constant herd/sell at weaning strategy. The difference is primarily due to the larger number of brood cows that can be carried by the sell at weaning strategy. The difference is also due to relatively lower cyclical net returns associated with grassfed stockers.

The low net returns generated for grassfed stockers raised questions concerning the correctness of the stocker model. Specifically, when examining total stocker returns (Table 4-10), stockers yielded net positive returns over stocker variable costs of production throughout the price cycle. This is logical because the stocker sale value is expected to be greater than stocker input costs. However, the stockers did not yield net positive returns over weaning values and production costs at any point in the cycle. This was unexpected as it was believed that retaining stockers in the herd would be profitable at some point in the price cycle. The inability of stockers to show a profit relative to weaned calves at any point in the cycle caused the stocker model productivity level to be questioned.

Review of the stocker model led to the conclusion that the stocker growth rates were probably too low. The failure to use a better quality supplemental ration was the reason for low stocker growth rates. The ration selected replaces shortages occurring in pasture forage availability in meeting minimum stocker nutritional levels. However, the ration did not allow nutritional levels that are needed for additional weight gains. Essentially the results indicate that backgrounding stockers on grass alone is not profitable. Such a system covers variable costs but not total costs of stocker production. These results tend to confirm the observation that very little strictly grass grazing backgrounding is done. However, the results of the baseline stocker strategies are correct for the supplemental ration assumptions made.

Very few ranches actually use this type of range supplement program. Rather, in practice, the ranches actually upgrade the stocker's overall grass/supplement intake with a higher quality supplement. The supplement then results in more rapid growth rates than reported here but at a higher cost. The question of stocker productivity adjustments will be addressed in the following section.

Stocker Productivity

The baseline stocker production systems utilized low grade supplement rations designed only to replace grass forage. This production system resulted in an average of approximately 120 pounds of growth from a steer between October 1 and July 1. This amount of growth was shown to be unprofitable. The first question answered in reflecting upon the low growth level for stockers was "what amount of stockers growth is necessary to breakeven with a mixed cow-calf-stocker system?" Simulations with the model indicated that approximately a 70 percent increase in stocker growth was needed to breakeven when the cow-calf-stocker herd mix and stocker sales date developed in Strategy 2 are followed. This rate of growth resulted in approximately 205 pounds of gain from October 1 to July 1. Net returns with this assumed rate of stocker growth are reported for each of the 12 cycle years in Table 4-14. Table 4-14 also directly compares the net returns with this improved stocker growth rate to those achieved under Strategy 2 with the original or "base" growth rate. With the stocker growth improved 70 percent, six years of positive and six years of negative net returns are encountered. Net returns summed over the cycle are $17.71 or essentially zero/breakeven returns. Even though the level of returns has been raised by this adjustment to growth, the pattern of net returns to the herd over the cycle is still essentially the same. The highest net returns are still earned in the years just prior to the peak of the price cycle, i.e. years 11 and 12. The greatest losses occur in the down phase of the cycle and near the cycle bottom.

After determining the growth rates required to breakeven with a mixed cow-calf-stocker operation, the next question to be addressed was what type of supplemental stocker rations and growth rates appear representative of North Eastern Oklahoma stocker cattle production systems. The simulation model developed for this thesis was not designed to answer this type of question. In fact a shortcoming of the model is that it can not readily consider alternative supplemental

TABLE 4 - 14

NET RETURNS OVER A 12 YEAR PRICE CYCLE WITH DIFFERENT STOCKER GROWTH RATES UTILIZING THE CONSTANT HERD SIZE/SELL STOCKERS IN JULY STRATEGY[1]

Year of the Price Cycle	Stocker Growth Rates: Base Growth Rate	Base Growth Rate Inreased by 70 Percent	Base Growth Rate With Final Stocker Weight Increased by 200 lbs
	Net Returns ($)	Net Returns ($)	Net Returns ($)
1*	439.82	1189.56	2522.02
2	-47.88	655.47	1874.17
3	-752.85	-51.02	995.77
4	-1304.34	-745.94	117.89
5	-1734.66	-1321.81	-608.57
6	-1867.83	-1399.68	-748.99
7	-1657.38	-1176.66	-497.23
8	-1173.91	-647.99	148.32
9	-529.58	80.74	1048.91
10	83.13	759.19	1908.01
11	516.02	1245.53	2542.59
12	654.28	1430.32	2793.84
Net Returns Over the 12 Year Price Cycle	-7374.98	17.71	12,096.73

*Year 1 is the peak of the 12 year price cycle. [1]As low quality forage and supplements over the winter months tended to yeild low, "biased" stocker growth rates, the stocker growth rates were increased to yeild "normal" stocker growth. Returns from the improved stocker growth are believed to be typical. The stable herd indicated 57.0 cows, 8.1473 replacements and 43.1261 stockers.

rations and stocker growth rates. Changing the stocker growth rate is feasible, but determining a realistic ration and ration cost to associate with a new growth rate can not be studied with this model. However, Brorsen's model (1980) is capable of addressing this question.

Base productivity was then increased by 200 pounds for an average of approximately 320 pounds wean to sale growth or an average of 1.33 lbs. of daily gain--an average felt to be typical of north central Oklahoma. The increased growth resulted in an overall cycle net profit of $12,000. Years showing positive net profits were increased to nine, however, the pattern of net returns is essentially the same with highest returns just prior to the peak of the price cycle and greatest losses near the bottom of the cycle (Table 4-14). Although the increased growth rate did not increase strategy 2 net profits to the levels attained by strategy 1, it improved profits considerably when compared to the 57-head cowherd/sell at weaning strategy.

When observing individual stocker performance, larger-faster growing stockers exhibited higher net returns. Because the model generated distributions around each growth rate, the higher returns are primarily attributed to rapidly growing productive calves. The weaning weight of the calves plays a secondary part in increased returns given by larger calves and becomes less and less important as the calf growth rate is increased, i.e. a calf calved on February 15 and weaned with an 80 pound advantage will remain a heavier calf under the baseline low growth rate regardless of its individual growth rate but may become an average or below average stocker when overall stocker growth rates are increased by improving the supplement. To further examine this, an efficient steer that exhibited a high baseline sales weight of 650.0 lbs. through 699.0 lbs. was considered. For the base growth rate the steer returned seven years of net gains over weaning during a 12-year cycle (Figure 4-3). Figure 4-3 shows the returns for an "efficient" faster growing steer. At base growth rates, steer #1 shows returns of over $200.00 going into the peak of the price cycle and drops in value rapidly as the feed price cycle peaks. The steer value then flattens and continues to drop until the bottom of the steer price cycle. As feed prices also bottom shortly afterward, the heavy steer then rapidly increases in value over the upphase of the cattle price cycle. Net returns over weaned value peak two years prior to the peak of the cattle price cycle with net returns over weaned value for seven of the 12 years. Net profits over the cycle were essentially "breakeven" for the "efficient" steer (Table 4-15).

Increasing growth rates by 70 percent allowed the steer to yield positive returns over weaning for 10 years of the 12 year cycle (Figure 4-3). Steer #2 shows returns of an "efficient" steer with a growth rate of 170 percent of the base which is viewed as a normal growth rate. Steer #2 yielded returns of $233.47 to $171.90 with net returns over weaning value of $27.90 to a loss of $1.36. Increasing the base growth by 200 lbs. yielded net returns of $460.97 an "efficient" steer. Insights from this analysis indicate that net returns could be increased by differentiating between stockers when selecting calves to be held as stockers (Table 4-15). Also,

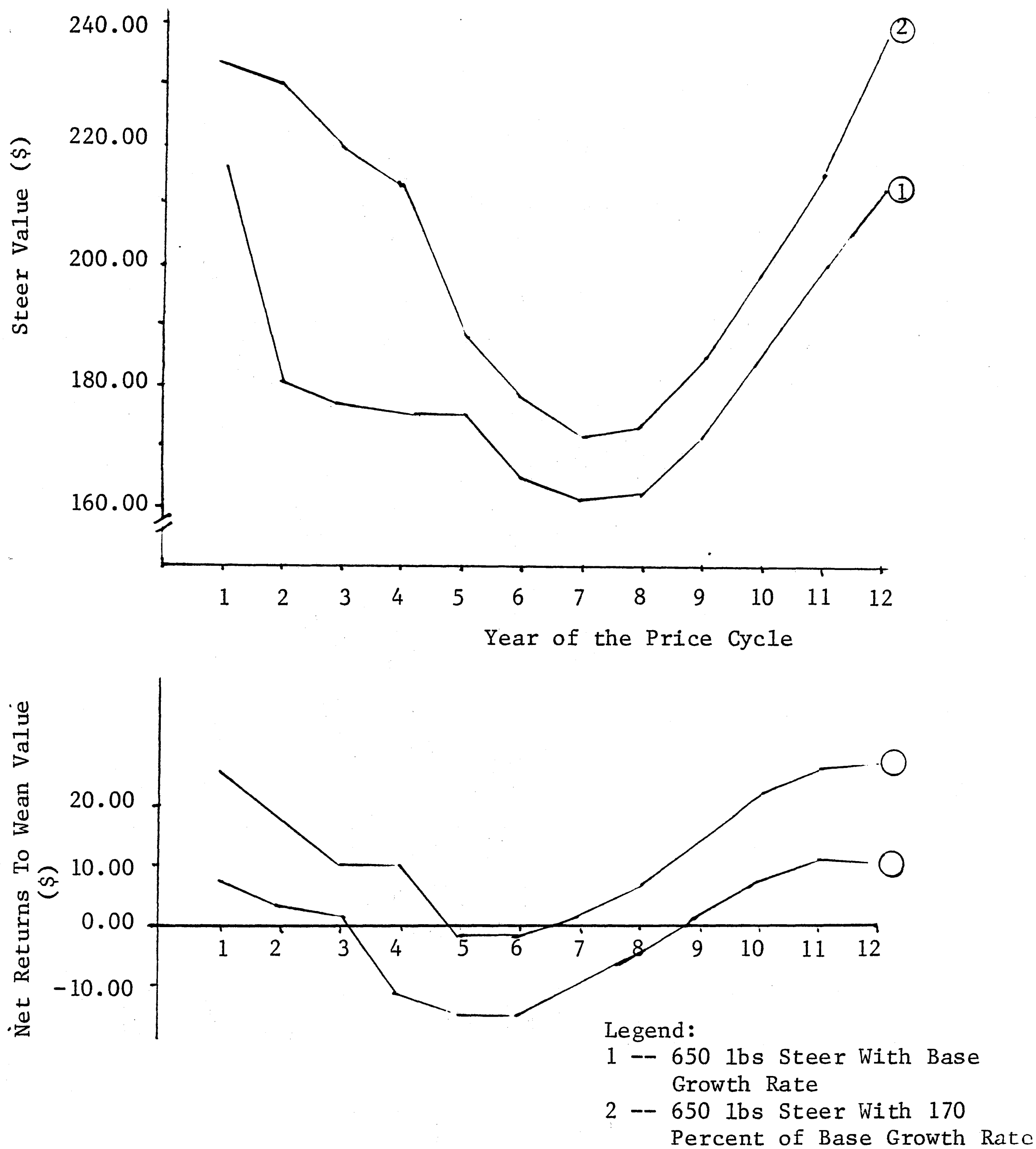


Figure 4-3. Stocker Steer Value for "Efficient" Steers Over a 12 Year Price Cycle

TABLE 4 - 15

AN EFFICIENT STEER'S[1] RETURNS ABOVE VARIABLE COSTS AND WEANED SALES VALUES OVER 12 YEAR PRICE CYCLE FOR THE CONSTANT HERD STRATEGY/SELL STOCKERS IN JULY STRATEGY[2]

	Steer Growth Rates					
	Base Growth Rate		Base Growth Rates Increased by 170%		Base Growth Rates With Final Stocker Weight Increased by 200 lbs	
Year	Steer Sales Value ($)	Net Profits Over Weaned Value ($)	Steer Sales Value ($)	Net Chance Over Weaned Value ($)	Steer Sales Value ($)	Net Change Over Weaned Value ($)
1*	216.20	7.44	233.74	24.71	262.79	59.23
2	180.29	3.39	230.40	18.33	250.18	49.24
3	176.90	2.02	219.73	10.51	220.46	18.12
4	190.01	-11.02	213.34	-1.36	199.60	8.76
5	175.62	-14.06	188.30	-0.98	169.59	-5.48
6	164.56	-14.10	177.93	2.33	164.03	-2.02
7	160.94	-8.85	171.90	7.32	195.80	34.94
8	162.51	-3.89	173.70	15.17	208.41	44.97
9	172.10	2.87	184.37	22.38	226.61	55.55
10	185.94	8.56	199.78	22.38	245.54	63.88
11	200.32	11.55	215.80	27.02	260.10	67.74
12	211.40	11.16	228.13	27.90	266.42	66.04
Net Value of a 12 year cycle	2196.79	-4.86	2436.85	163.73	2679.53	460.97

*Year 1 is the peak of the price cycle. [1]An efficient steer is assumed to be a steer weighing 650.0 lbs in July under the standard growth rate. [2]The stable herd size indicates 57.0 cows, 8.1473 replacements, and 43.1261 stockers.

differentiating between stockers at points throughout the year and selling the less efficient stockers early appears to be beneficial to the ranch.

Summary of Baseline Strategies

Baseline strategies indicate that in constant herd strategies, a 100-head cow-calf operation with calves sold at weaning yields higher returns than a similar constant size mixed stocker/cow herd strategy. Results indicate that stockers help spread fixed costs of the ranch. Mixed stocker/cow herd strategies show positive net returns around the peak of the cycle, and stockers yield net positive returns over weaning values around the peak of the price cycle. As expected, stocker growth rates affect net profits. Indeed it appears that stocker grazing is not in general profitable unless a type of supplement is used that upgrades the quality of the native grass ration obtained from grazing alone.

Variable Herd Size and Composition Strategies

The literature review revealed that numerous researchers including King, Trapp, and Bentley et al. found that returns to breeding herd investments can be increased by following variable herd size strategies when output prices are cyclical. None of these studies actually established an optimal breeding herd size adjustment except Trapp. The others developed pragmatic strategies that increased returns over constant herd size strategies. The latter approach is taken here. A pragmatic strategy will be sought that performs better than the baseline constant herd size strategies.

The process of developing and solving for a theoretically verifiable optimal strategy, as Trapp does for a cowherd, is beyond the scope of this thesis. However, the unique extension attempted in this thesis allows the search for a profit increasing variable herd size strategy to be extended. It allows not only the size of the herd to vary but the cow-calf-stocker composition to vary as well.

Analysis of the baseline model results confirms what other researchers have observed--returns to brood cows vary depending on the phase of the price cycle. Hence, the potential exists to increase profits by increasing herd size when returns will be higher. In essence, the baseline models indicate that replacement heifers have the greatest possible returns, or net present value, if they enter the herd near the bottom of the cycle. The baseline models also indicate that stockers have variable rates of return. However, stockers seem to experience the highest rate of return around the peak of the cycle. Intuitively, this implies that a combined variable herdsize/composition strategy as follows may work well. A maximum number of replacement heifers should be held during the two to four years surrounding the bottom of the price cycle. These heifers should then be held for some six to eight years until the peak of the price cycle. At that time, more stockers should be held to replace cows being culled and the overall herd size should perhaps be increased at this point since prices relative to costs are at a maximum. During the downphase of the price cycle, a relatively small herd size should be maintained, and replacements should be delayed to the extent possible until a turn in the price cycle is approached. The following strategies will attempt to test this general hypothesis and to capitalize upon it when possible, or develop a new hypothesis to attempt to capitalize upon.

Strategy 4—Constant Herd Size/Mixed Cow-Calf-Stocker Strategy

This strategy was based upon keeping the herd size at a constant 100-head cow-equivalent size but letting the cow-calf-stocker mix vary over the cycle. Priority was given to varying cow numbers cyclically below 100-head to take advantage of the price cycle. Stockers were viewed as secondary income to cows and were held as residuals when needed to maintain a 100-head cow-equivalent herd. All weaned calves that were held as stockers were sold in July. Because of the July sales date, it is assumed that a stocker or replacement heifer replaces approximately 90 percent of a cow. Stocker growth rates that are increased to 170 percent of the base values were believed to be more typical of growth rates normally observed, these faster growth rates were utilized in the model.

Strategy 4 was to develop a constant herd size strategy that incorporated stockers into the herd whenever their contributions were felt to exceed those of the cows they replaced. The specific decisions to be made were: when should stockers be held and what pattern of culling and replacement should occur over the 12-year cycle? Utilizing the information gleaned from Strategy 2, the years showing positive net profits when stockers were incorporated into the herd were years 10, 11, 12, and one, i.e. the four years preceding to the peak of the cycle. The decision then was to determine when to "step up" culling and replacement. It was hypothesized that replacement heifers should be held at the bottom of the price cycle when heifer prices were relatively "cheap." Heifers held at the bottom of the cycle would then reach maximum productivity during the years surrounding the peak of the cycle and be available for sale as cull cows near the bottom of the next cycle. The strategy, then, was to hold stockers over the peak of the cycle and replacements over the bottom of the cycle. No replacements will be held when stockers are held. Because the cow age structures change throughout the price cycle, cows are culled as percentages of the herd rather than by age. For example, the oldest 15 percent of the cows are culled in high culling/replacement years rather than culling cows of seven years and older.

The hypothesized Strategy 4A for the constant herd size model, then, is to increase culling and replacements in years six through nine and hold stockers in years 10 through the peak of the cycle (years 10 through 12 and one). Replacements were added as needed to maintain the 100-head cow equivalent herd cover performance failures and deaths for years two through five. The constant herd size was set at 100 cow-equivalents or the lowpoint on the cost curve.

Strategy 4A yield net returns of $14,734.59 over the cycle with positive net returns for 10 of the 12 years. Net returns ranged from a high of $4,487.40 in year one to a loss of $2,594.91 in year seven (Table 4-16).

TABLE 4 - 16

PRAGMATIC STRATEGIES FOR CONSTANT HERD SIZE = 100 COW-EQUIVALENTS, MIXED COW-CALF STOCKER STRATEGIES

	Net Returns ($)	
Year of the Price Cycle	Strategy $4A_1$	Strategy $4B_2$
1*	4487.40	5170.45
2	590.87	4861.07
3	1337.47	3826.91
4	1742.43	-2379.77
5	600.53	-2222.81
6	186.43	593.56
7	-2594.91	-1865.78
8	-4.34	600.54
9	210.98	2809.23
10	472.07	493.32
11	3397.68	3653.58
12	4307.93	4756.65
Net Returns Over the Cycle	14,734.59	19,023.51

Strategy A_1, cull 15% of cows and maximize replacements yrs 6-9, hold stockers yrs 10-12, and 1. Strategy B_2, cull 15% of cows and maximize replacements yrs 6-9, hold stockers yrs 10-12, and 1-3. *Year one is the peak of the price cycle.

When viewing stocker performance in Strategy 3, it was indicated that profits may be improved by holding stockers for additional two years following the peak of the cycle. Strategy 4 was then changed to incorporate stockers for the six years surrounding the peak of the price cycle, i.e. years two and three as well as years 10 through 12 and one. No replacements were held during the years in which stockers were held.

Strategy 4B yielded net returns of $19,023.51 over the cycle for an improvement of $4,288.92. Net profits were generated for three of the 12 years. Net profits ranged from a loss of $2,379.77 in year four to a high of $5,170.45 in year one (Table 4-16). Specifically, the brood cow herd is allowed to sink to 78 percent of its normal capacity over the peak of the cycle as stockers take advantage of "high" prices and replace brood cows. As a result of the "shrunk" brood cow herd, large numbers of replacements are held in year four to rebuild the cow herd. One problem with Strategy 4B is that it takes two years (i.e. years four and five) to rebuild the herd to 100 cow-equivalent units and it is unprofitable to hold stockers in year four. Culling and replacement is "stepped up" for years six through nine to "gear up" for the peak price years (Table 4-17). Increasing stocker growth would improve net profits from Strategy 4B to $20,297.04.

Strategy 5 was to develop a variable herdsize strategy that incorporated stockers into the herd whenever their contributions were felt to exceed those of the cows they replaced. The primary decision to be made in the variable herdsize strategy is the size of the herd at various points in the cycle. In this regard, observation of the

TABLE 4 - 17

NET PROFITS AND HERD STRUCTURE FOR THE CONSTANT HERD SIZE/MIXED COW-CALF-STOCKER STRATEGY 4B

Year	Number of Cow Equivalent Units	Number of Cows	Number of Replacement Heifers	Number of Stockers	Number of Cows Culled	Age of Oldest Cow	Net Profits ($)
1*	100.0	86.4381	0.0000	15.0687	1.9162	9	5170.45
2	100.0	82.5043	0.0000	19.4396	2.1103	10	4861.07
3	100.0	77.9437	0.0000	24.5072	2.5123	11	3826.91
4	97.0	72.6985	24.4062	0.0000	3.0000	12	-2379.77
5	100.0	90.7076	9.4783	0.0000	3.4946	13	-2222.81
6	100.0	78.9190	21.5026	0.0000	18.0609	12	593.56
7	100.0	79.8453	20.5578	0.0000	17.6725	12	-1865.78
8	100.0	80.9383	19.4430	0.0000	16.9343	11	600.54
9	100.0	81.9455	18.4156	0.0000	16.3738	5	2809.32
10	100.0	97.1582	0.0000	3.1100	1.4289	6	493.32
11	100.0	93.7081	0.0000	6.9908	1.7305	7	3653.58
12	100.0	90.1236	0.0000	10.9737	1.9360	8	4756.65
Net Profit Over the Cycle							$19,023.51

*Year 1 is the peak of the 12 year price cycle. [1]Cow age is expressed as the number of years in the herd, i.e. the number of calves produced.

total cost curve shows that relatively rapid increases in cost per cow-equivalent unit begin to occur at 119-head. Given this, and the fact that the cost curve is at a minimum at 100-head, herd sizes between 100 and 119-herd seem to be logical. The secondary decision to be made is how should the herd composition changes over the cycle--specifically when should stockers be held and what pattern of culling and replacement should occur over the cycle. Utilizing the information gleaned in Strategy 4 for a constant herd size, but with a varying cow-calf-stocker composition, it was hypothesized that the variable herd size strategy developed should have the largest number of replacements held over the four lowest years of the price cycle and it should hold stockers over the peak of the price cycle.

The basic logic to be tested in the variable herdsize/variable composition strategy is as follows. It appears that the fixed resources of the firm, specifically pasture, should be stressed the most during the peak of the cycle. A problem with doing this with only a cow-calf herd is that if heavy replacement continues into the peak of the price cycle and somewhat beyond, the ranch has a large number of young cows it will hold through the next low point of the price cycle. These cows will be too young to be culled and replaced when the bottom of the cycle occurs. Thus new replacements that are expected to carry the firm through the next peak of the cycle cannot be kept. The hypothesized remedy is to maintain a large herd over the peak of the cycle by holding stockers instead of cows. Ceasing to build brood cow numbers midway through the upphase of the price cycle will generate a large number of cullable aged cows near the next bottom of the cycle. Also, holding stockers over the peak of the cycle is hoped to take advantage of the high prices at the cycle peak by "stretching" the firm's capacity to the limit.

In exploring the above hypothesized strategy, six scenarios were tested. The first five of these scenarios will be briefly discussed with the primary purpose of this discussion to show the sequence of events and logic which lead to the last and most successful strategy. The herd size, composition, and net profits over a typical 12-year cycle for each of the six scenarios tested are given in Tables 4-18 to 4-25.

As a starting point the cow-calf herdsize pattern developed by Trapp in his publication "Cow Culling and Replacement Strategies for Cyclical Price Conditions" was combined with the stocker retention pattern developed in Strategy 4. Table 4-18 displays the nature of this strategy and its resulting net profits.

Herdsize for Strategy 5A varies from a low of 105.3 cow-equivalents in year 3 of the cycle to a high of 134.1 cow-equivalents in year 9 of the cycle. Stockers are held for two years over the peak of the cycle. Replacements and cullings follow guidelines established by Trapp for a herd having only brood cows and no stockers. Basically Trapp's strategy calls for heavy rates of replacements around the bottom of the price cycle (years six, seven, eight, and nine) with large numbers of culls at the same time. Heavy replacement also occurs during years three and four to build up the herd from low replacement years. Culling and replacement levels are both relatively low during the down phase of the cycle. Utilizing this scenario, a net income of $15,645.95 was realized.

TABLE 4 - 18

NET PROFITS AND HERD STRUCTURE FOR THE VARIABLE HERD SIZE/MIXED COW-CALF-STOCKER STRATEGY 5A

Year	Number of Cow Equivalent Units	Number of Cows	Number of Replacement Heifers	Number of Stockers	Number of Cows Culled	Age of Oldest Cow	Net Profits($)
1*	113.1	113.1387	0.0000	0.0000	2.5768	9	6938.18
2	108.3	108.2856	0.0000	0.3494	2.5707	10	6894.94
3	105.3	102.6782	0.0000	2.9133	3.0599	11	5726.87
4	111.8	96.1922	17.3212	0.0000	3.6829	12	1457.29
5	117.1	105.7197	12.6629	0.0000	4.3613	13	-1415.75
6	120.2	92.8954	30.3263	0.0000	21.5474	12	-250.71
7	121.9	97.7759	26.8764	0.0000	21.7130	12	-2946.01
8	126.6	100.1527	29.4624	0.0000	21.8380	12	-4248.51
9	134.1	105.4622	31.8507	0.0000	21.3340	5	-4383.50
10	133.0	133.0800	0.0000	0.0000	1.7960	6	-714.11
11	128.5	128.4700	0.0000	0.0000	2.2895	7	3541.89
12	118.0	117.9639	0.0000	0.0000	2.5424	8	5045.37
Net Profit Over the Cycle							$15,645.95

TABLE 4 - 19

NET PROFITS AND HERD STRUCTURE FOR THE CONSTANT HERD SIZE/MIXED COW-CALF-STOCKER STRATEGY 5B

Year	Number of Cow Equivalent Units	Number of Cows	Number of Replacement Heifers	Number of Stockers	Number of Cows Culled	Age of Oldest Cow	Net Profits ($)
1*	117.1	113.1387	0.0000	4.8487	2.5768	9	5874.62
2	112.6	108.2856	0.0000	4.7939	2.5707	10	5849.93
3	110.3	102.6782	0.0000	8.4688	3.0599	11	5094.03
4	110.5	96.1922	17.3212	0.0000	3.6829	12	414.38
5	115.7	105.7197	12.6629	0.0000	4.3613	13	-1958.42
6	120.7	92.8954	30.3263	0.0000	21.5474	12	-386.80
7	127.8	97.7759	26.8764	0.0000	21.7134	12	-3076.95
8	129.6	100.1527	29.4624	0.0000	21.1838	12	-4436.77
9	135.9	105.4622	31.8507	0.0000	21.3340	5	-74.14
10	133.0	133.0800	0.0000	0.0000	1.7960	6	-1950.00
11	138.9	128.4700	0.0000	11.6848	2.2895	7	3094.45
12	129.0	117.9639	0.0000	10.3623	2.5426	8	4924.42
Net Profit Over the Cycle							$13,368.80

*Year 1 is the peak of the 12 year price cycle. [1] Cow age is expressed as the number of years in the herd, i.e. the number of calves produced.

TABLE 4 - 20

NET PROFITS AND HERD STRUCTURE FOR THE VARIABLE HERD SIZE/MIXED COW-CALF-STOCKER STRATEGY 5C

Year	Number of Cow Equivalent Units	Number of Cows	Number of Replacement Heifers	Number of Stockers	Number of Cows Culled	Age of Oldest Cow	Net Profits ($)
1*	112.6	106.5414	0.0000	6.7318	2.2585	9	5676.12
2	108.6	101.9425	0.0000	7.5973	2.4399	10	5741.96
3	105.3	96.6252	0.0000	9.6388	2.9035	11	5038.91
4	104.5	90.4800	16.5363	0.0000	3.4892	12	546.76
5	109.8	99.6566	11.2643	0.0000	4.1253	13	-1435.86
6	112.5	86.9966	28.3595	0.0000	20.2232	12	85.03
7	114.1	91.4969	25.1450	0.0000	20.3536	12	-2470.82
8	118.6	93.6237	24.5425	0.0000	19.8354	12	-3774.60
9	121.9	98.6237	24.7618	0.0000	19.9484	5	1199.49
10	122.9	119.5256	0.0000	3.7869	1.6827	6	-982.75
11	120.9	115.3213	0.0000	6.2434	2.1150	7	3295.91
12	117.9	110.9214	0.0000	7.3095	2.3686	8	4897.11
Net Profit Over the Cycle							$17,817.52

*Year 1 is the peak of the 12-year price cycle. [1]Cow age is determined by the number of years in the herd, i.e. the number of calves produced.

TABLE 4 - 21

NET PROFITS AND HERD STRUCTURE FOR THE VARIABLE HERD SIZE/MIXED COW-CALF-STOCKER STRATEGY 5D

Year	Number of Cow Equivalent Units	Number of Cows	Number of Replacement Heifers	Number of Stockers	Number of Cows Culled	Age of Oldest Cow	Net Profits ($)
1*	103.1	103.1588	0.0000	0.0000	2.2096	9	5729.41
2	98.7	98.7043	0.0000	0.0000	2.3673	10	5839.60
3	105.0	93.7043	0.0000	12.8524	2.8120	11	4908.49
4	105.0	87.6230	17.7245	0.0000	3.3690	12	184.24
5	105.0	98.2241	6.9114	0.0000	3.9732	13	-505.79
6	110.0	82.3694	28.1832	0.0000	19.2460	12	49.36
7	110.0	87.6134	23.7913	0.0000	19.5632	12	-2140.87
8	115.0	89.4625	26.3399	0.0000	18.9420	12	-3217.54
9	119.0	94.1325	25.3648	0.0000	19.1146	5	1794.83
10	115.7	115.7748	0.0000	0.0000	1.6085	6	-949.51
11	111.7	111.7113	0.0000	0.0000	2.0358	7	3300.95
12	107.5	107.4465	0.0000	0.0000	2.3100	8	4887.15
Net Profit Over the Cycle							$19,880.32

*Year 1 is the peak of the 12-year price cycle. [1]Cow age is determined by the number of years in the herd, i.e. the number of calves produced.

TABLE 4 - 22

NET PROFITS AND HERD STRUCTURE FOR THE PRAGMATIC VARIABLE HERD SIZE/MIXED COW-CALF-STOCKER STRATEGY 5E

Year	Number of Cow Equivalent Units	Number of Cows	Number of Replacement Heifers	Number of Stockers	Number of Cows Culled	Age of Oldest Cow	Net Profits($)
1*	115.0	99.7610	0.0000	16.9322	2.1336	9	5485.05
2	105.0	95.4734	0.0000	10.5852	2.2756	10	5627.04
3	105.0	90.5167	0.0000	16.0926	2.6980	11	4643.00
4	99.8	84.8261	15.4774	0.0000	3.232	12	332.89
5	99.8	93.5024	6.6275	0.0000	3.8099	13	-330.03
6	102.5	78.4106	26.8806	0.0000	18.355	12	-86.51
7	103.75	83.4136	22.6150	0.0000	14.9118	12	-2264.32
8	107.5	85.0822	25.0032	0.0000	18.0610	12	-3135.87
9	113.0	89.4047	26.1072	0.0000	18.2189	5	2075.54
10	115.0	111.9359	0.0000	3.4385	1.5283	6	55.33
11	115.0	108.0336	0.0000	7.8041	1.9438	7	3230.65
12	115.0	103.8989	0.0000	12.3347	2.2460	8	4777.13
Net Profit Over the Cycle							$20,409.99

*Year 1 is the peak of the 12-year price cycle. [1]Cow age is determined by the number of years in the herd, i.e. the number of calves produced.

TABLE 4 - 23

NET PROFITS AND HERD STRUCTURE FOR THE VARIABLE HERD SIZE/MIXED COW-CALF-STOCKER STRATEGY 5F

Year	Number of Cow Equivalent Units	Number of Cows	Number of Replacement Heifers	Number of Stockers	Number of Cows Culled	Age of Oldest Cow	Net Profits ($)
1*	130.0	117.1376	0.0000	14.2916	2.7532	9	5869.73
2	112.1	112.1306	0.0000	0.0000	2.6528	10	6379.84
3	110.0	106.3507	0.0000	4.0547	3.1438	11	5216.80
4	115.0	99.7026	17.2719	0.0000	3.7700	12	405.55
5	115.0	109.0392	8.7084	0.0000	4.4500	13	-1165.73
6	122.5	92.2402	31.3721	0.0000	21.5568	12	-207.77
7	122.5	97.9516	26.6173	0.0000	21.8686	12	-3097.77
8	125.0	97.8961	28.9243	0.0000	21.2230	12	-4425.09
9	130.0	105.0166	31.5339	0.0000	21.4034	5	975.33
10	132.3	132.3340	0.0000	0.0000	1.7947	6	-1606.95
11	130.0	127.7350	2.5256	0.0000	2.2859	7	3132.47
12	130.0	122.2437	0.0000	8.618	2.6776	8	4958.20
Net Profit Over the Cycle							$16,434.61

*Year 1 is the peak of the 12-year price cycle. [1]Cow age is determined by the number of years in the herd, i.e. the number of calves produced.

TABLE 4 - 24

NET PROFITS FOR THE VARIABLE HERD SIZE/MIXED COW-CALF-STOCKER MODEL FOR SELECTED PRAGMATIC STRATEGIES--HERD SIZES DEVELOPED FROM TRAPP'S OPTIMIZED VARIABLE HERD SIZE MODEL

	Net Profits and Herd Size					
	Strategy 5A		Strategy 5B		Strategy 5C	
Year of Price Cycle	Herd Size in Cow-Equivalents	Net Income	Herd Size in Cow-Equivalents	Net Income	Herd Size in Cow-Equivalents	Net Income
1*	113.1	6938.18	117.1	5874.62	112.6	5676.12
2	108.3	6894.94	112.6	5849.93	108.6	5741.96
3	105.3	5726.87	110.3	5094.05	105.3	5038.91
4	111.8	1457.29	111.5	414.38	104.5	546.76
5	117.1	-1415.75	115.7	-1958.42	109.8	-1435.86
6	120.2	-250.71	120.7	-386.80	112.5	85.03
7	121.9	-2946.01	127.8	-3076.92	114.1	-2470.82
8	126.6	-4248.51	129.6	-4436.77	118.6	-3774.60
9	134.1	-4383.50	135.9	-74.14	121.9	1199.49
10	133.0	-714.11	133.0	-1950.00	122.9	-982.75
11	128.5	3541.89	138.9	3094.45	120.9	3295.91
12	118.0	5045.37	129.0	4924.42	117.9	4897.11
Net Income Over Cycle		15,645.45		13,368.80		17,817.52

1=Herd size and culling strategy developed by Trapp; 2=herd size and culling strategy developed by Trapp with herd size increased by replacement herd developed by Trapp increased by 150 percent; 3=herd size developed by Trapp and culling developed by author.

Source: Trapp and interpolations by author.

TABLE 4 - 25

NET PROFITS FOR THE VARIABLE HERD SIZE/MIXED COW-CALF-STOCKER MODEL FOR SELECTED PRAGMATIC STRATEGIES--HERD SIZES DEVELOPED BY AUTHOR

	Net Profits and Herd Size					
	Strategy 5D		Strategy 5E		Strategy 5F	
Year of Price Cycle	Herd Size in Cow-Equivalents	Net Income	Herd Size in Cow-Equivalents	Net Income	Herd Size in Cow-Equivalents	Net Income
1*	103.1	5729.41	115.0	5485.05	130.0	5869.73
2	98.7	5839.60	105.0	5627.04	112.1	6379.84
3	105.0	4908.49	105.0	4643.00	115.0	5216.80
4	105.0	184.24	100.0	332.89	115.0	405.55
5	105.0	-505.79	100.0	-330.03	115.0	-1165.73
6	110.0	49.36	102.5	-86.51	122.5	-207.77
7	110.0	-2140.87	103.8	-2264.23	122.5	-3097.77
8	115.0	-3217.54	107.0	-3135.87	125.0	-4425.09
9	119.0	1794.83	113.0	2075.54	130.0	975.33
10	115.7	-949.51	115.0	55.33	132.3	-1606.95
11	111.7	3300.95	115.0	3230.65	130.0	3132.47
12	107.5	4887.15	115.0	4777.13	130.0	4958.20
Net Income Over Cycle		19,880.32		20,409.99		16,434.61

1= herd size and strategy developed by author; 2= herd size and strategy developed by author and selected as the pragmatic best strategy; 3= herd size and strategy developed by author with herd size increased.

In Strategy 5B the replacement numbers used in Strategy 5A were increased by 50 percent and stockers were held for the five years around the peak of the cycle. The increased herd size allowed more stockers to be held. This was done to test the sensitivity of Strategy 5A to herdsize. The resulting increases in herdsize caused greater increases in costs than revenues and reduced profits to $13,368.80. This verified the initial hypothesis that no more than approximately 119 cow-equivalents units should be held (Table 4-19).

Strategy 5C (Table 4-20) continues to use Trapp's herdsize pattern but now uses the culling and replacement strategy developed in Strategy 4. The stocker retention pattern developed in Strategy 4 was also used. The highest culling and replacement period was in years six, seven, eight, and nine. Numbers of heifers kept for replacement were increased over years four and five as the herd "built up" from the years when stockers replaced cows. Stockers were held in the six years over the peak, years 10 through 12, and years one through three. The herd size ranged from a low of 104.5 cow-equivalents in year four to a maximum of 122.9 cow-equivalents in year ten. Net profits over the cycle ranged from a loss of $3,774.60 in year eight to a high of $5,741.96 in year two for a net profit over the entire cycle of $17,817.52.

As the maximum profitable herd size appeared to be 119 cow-equivalents, and the pattern appeared to favor increased herd sizes for years six through 12, herd size was maximized in those years. Strategy 5D (Table 4-21) used the culling and replacement strategy developed in Strategy 4 and, when the herd size allowed, used the stocker retention pattern developed in Strategy 4. The herd size varied from a low of 98.7 cow-equivalents in year two to a high of 119.0 cow-equivalents in year nine. Due to herd size restraints stockers were held only in year three. Net income over the cycle was $19,880.32.

The herdsize was then constrained to have a minimum of 100 cow-equivalents and to be a size that encouraged stocker retention for each of the six years over the peak of the cycle. Culling, replacement, and stocker retention strategies followed those developed in Strategy 4. Observation of the results of Strategies 4, 5C, 5D, and the cost structure indicated a maximum herd size of 115 cow-equivalents. Strategy 5E (Table 4-22) had a maximum herd size of 115.0 cow-equivalents in years 10 through 12 and a herd size of over 110.0 cow equivalents in years one and nine through 12. Net profits ranged from a loss of $3,135.87 in year eight to $5,627.04 in year two with net profits over the cycle of $20,409.99. Cow-equivalents were then extended to higher levels in Strategy 5F. As confirmed in Strategy 5B, costs associated with herd sizes over 119 cow-equivalents offset gains in revenue associated with larger herd sizes. Net profits for Strategy 5F were lowered to $16,434.61 (Table 4-23).

Table 4-24 and Table 4-25 summarize the results of the six variable herd size and herd structure strategies. Lowest net returns were for Strategy 5B which combined unprofitably large herd sizes with a less than optimal culling/replacement/stocker retention strategy. Strategy 5E had the highest net profit of $20,409.99 and was selected as the best pragmatic variable herd size strategy.

Strategy 5E maximizes herd size during the years from the bottom to the peak of the price cycle. The herd size at the bottom of the cycle allows the model to place heifers cheaply and lets cull cow income offset losses incurred by placing heifers. Large herd sizes around the price cycle peak allow the producer to take advantage of high prices by holding stockers. Transition herd sizes allow the herd to dwindle in size as prices decline in the down phase of the price cycle. The minimal herd size occurs when prices have fallen to below average levels and during a period when replacement heifers would enter the herd at a disadvantage. A second transitional herd size allows the herd to begin to build just prior to the maximum replacement period. The initial herd buildup allows the number of productive cows to increase just prior to increasing the replacements.

Specifically, Strategy 5E holds 115 cow-equivalents for years 10 through 12, 114 cow-equivalents for year one, 105 cow-equivalents for years two and three, 99.8 cow-equivalents for years five and six, and then rebuilds the herd in years six through nine. The cow herd reaches a minimum of 78.4106 cows in year six to a peak of 111.9359 cows in year 10. Replacements are maximized in years six through nine. Heavy retention of heifers in year four builds the herd back up after the stocker retention years. Stockers are held over years 10 through 12 and one through three. Net profits ranged from a high of $5,627.04 in year two to a loss of $3,135.87 in year eight. Positive net profits were yielded for eight of the 12 years with heaviest losses occurring in the replacement years of seven and eight (Table 4-26).

Previous research indicated that net profits can be increased by 15 percent by varying the herd size. The pragmatic variable herd size Strategy 5E increased net profits over the constant herd size Strategy

TABLE 4 - 26

ANNUAL COSTS AND RETURNS OVER A 12 YEAR PRICE CYCLE FOR THE PRAGMATIC VARIABLE HERD SIZE STRATEGY 5E

Annual Summary of Total Costs and Income ($)

Year	Brood Cow Maintenance Costs	Replacement Maintenance Costs	Stocker Steer Maintenance Costs	Stocker Heifer Maintenance Costs	Stocker Steer Revenue	Stocker Heifer Revenue	Cull Cow Revenue	Market Value of Steers at Weaning	Market Value of Heifers at Weaning	Net Profit
1*	9072.79	0.00	532.00	525.23	8678.91	7154.34	381.82	8229.12	6798.91	5485.05
2	9121.59	0.00	342.00	338.87	8223.25	6822.33	383.91	7969.21	6621.72	5627.04
3	8646.00	0.00	523.66	518.88	7585.30	6323.05	423.18	7253.35	6063.04	4643.00
4	8215.55	1291.87	0.00	0.00	6280.75	3082.58	476.99	6280.75	3082.58	332.89
5	8967.78	554.31	0.00	0.00	5187.72	3478.16	526.19	5187.71	3478.16	-330.03
6	7326.17	2174.77	0.00	0.00	4984.31	995.47	3434.65	4984.31	995.47	-86.51
7	7703.96	1804.06	0.00	0.00	3952.19	789.44	2502.17	3952.19	789.44	-2264.23
8	7666.34	1930.10	0.00	0.00	4229.07	840.35	1391.15	4229.06	840.35	-3135.87
9	7810.03	1938.58	0.00	0.00	4669.90	995.99	6158.26	4669.90	995.99	2075.54
10	10240.92	0.00	101.64	100.96	5621.18	4607.31	270.37	5537.75	4544.04	55.33
11	10762.19	0.00	243.01	240.02	7763.31	6360.03	352.54	7556.05	6199.98	3230.65
12	10138.03	0.00	386.53	381.59	8397.56	6891.87	443.84	8057.40	6625.26	4777.13
Net Profit Over the 12 Year Price Cycle										$20,409.99

*Year 1 is the peak of the price cycle.

4B by 7.29 percent by varying the herd size (Table 4-17 and Table 4-26). Varying the herd size increased net profits over the cycle from $19,023.51 to $20,409.99. By increasing the productivity level of stockers to those attained by more productive stockers, Strategy 5E increases profits over the cycle to $23,587.06.

Low net profits associated with stockers is the primary reason that net returns generated by Strategy 5E did not attain the levels of the baseline sell at weaning Strategy 1. An optimal strategy may increase the returns associated with the variable herd size/mixed cow-calf-stocker strategy but, with the stocker growth rates utilized, it is questionable that the optimized strategy would yield significantly higher returns than the sell at weaning strategy. With the highest stocker growth rates simulated, net returns from Strategy 5E were comparable to those of the constant herd size/sell at weaning Strategy 2.

Summary of Variable Herdsize Strategies

Incorporating stockers into a cow herd appears to be a beneficial strategy during high price periods. The stockers also appear to warrant the increased pasture pressure during high price periods. Pasture pressure is also warranted during high replacement periods. However, stockers should be viewed as secondary sources of income.

Insights were gained into future research for determining optimal herd size and structure. The variable herd size mixed-cowcalf-stocker Strategy 5E showed a 7 percent gain over a similar constant herd size Strategy 4B with medium stocker growth and a 16 percent gain over the constant herd size Strategy 4B with improved stocker growth.

CHAPTER V

SUMMARY AND CONCLUSIONS

This thesis addresses the problem of whether a cow-calf producer can increase profits by holding weaned feeder calves for sale as grassfed stockers. The solution required determining when to hold stockers and developing a strategy for incorporating stockers into a variable herd size cow-calf system.

Systems analysis was the primary methodology utilized. An integrated cow-calf-stocker simulation model was developed for use in the analysis. Model parameters included: stocker productivity by weight, sex, and month; cow productivity by age; forage productivity by month; labor requirements by month; supplemental feed requirements by month; and other variable and fixed costs. Estimates of cyclical and seasonal price patterns were developed for steers, heifers, cull cows, and supplemental feed. Weaned calf weights were determined by the brood cow's age and the calf's birthdate. Differences in stocker weights reflected stocker weaning weights by brood cows age, calving date and growth rates of faster or slower growing stockers. As the stocker growth rates were expected to be normally distributed, a normally distributed variable length delay was used to distribute the weights associated with more (or less) efficient stockers. Economic criteria generated by the model include: daily, monthly, and annual costs and revenues for the brood-cow herd, replacement heifers, and stockers; cumulative costs and revenues over the life of a brood cow or stocker, and annual and cumulative costs and revenues for the ranch.

Two baseline strategies were developed that compared constant herd size strategies. In the first strategy, all calves were sold at weaning. In the second strategy, all stockers were held for sale in July. The largest revenues were generated by the 100-head cow herd constant herd size/sell at weaning strategy. As cows were found to be more valuable than stockers, the firm's gross receipts dropped when large numbers of cows were replaced by stockers.

Baseline strategies then compared a 57-head cowherd/hold all stockers for sale in July with a 57-head cow herd sell at weaning strategy. Again, the sale at weaning strategy yielded the highest net return over the cycle showing the unprofitability of stockers. However, the combined cow herd/stocker strategy showed a slight advantage for holding stockers during the years over the peak of the cycle. Because stocker growth rates used in the model were low and reflected minimal nutrition levels, the model was felt to be biased against stocker productivity. To correct the bias, two methods of increasing stockers productivity were developed: 1) the stocker growth parameters were increased by 70 percent, and 2) total stocker growth was increased by 200 lbs. Increased stocker productivity reversed the conclusions in favor of the cow herd/stocker model for the 57-head cowherd Strategies 2 and 3. For 57-head constant herd size models, a 70 percent increase in stocker productivity increased net profits over the cycle to break even. Additional stocker productivity raised net profits above break even. The cow herd/stocker scenarios tested did not attain the net profits over the cycle reflected by the 100-head cowherd/sell at weaning strategy.

Based on the observation that the combined cowherd-stocker scenarios showed gains by having stockers around the peak of the price cycle, flexible strategies were developed to selectively incorporate stockers into the herd, thus changing the herd composition mix, but holding herd size in cow-equivalents constant. Stockers were incorporated as residuals needed to reach the 100 cow-equivalent herd size. Replacement and culling strategies were also incorporated into the strategy. The mixed strategy maximized culling and replacement over the bottom of the cycle and held stockers over the peak of the cycle. This scenario approached but did not attain the net profits generated over a cycle by the 100 cowherd/sell at weaning constant herd size strategy.

The constant herd size/mixed cow-calf-stocker strategy which held stockers over the peak was then allowed to vary in total herd size. Simulations indicated that herd size should increase as prices rise and decrease as prices fall. Scenarios in which the herdsize varied increased net profits over a cycle by seven percent compared to the constant herd size/mixed cow-calf-stocker strategy. When efficient/faster growing stockers were assumed, scenarios indicated that a variable herd size/mixed cow-calf-stocker strategy increased the net profits over a cycle by more than 16 percent. Net returns over a cycle from the variable herd size/mixed cow-calf-stocker strategy were comparable to those obtained from the constant herd strategy/sell at weaning model.

Conclusions

Scenarios did not favor a mixed cow-stocker strategy over a low cost constant herd size/sell calves at weaning strategy. However, scenarios indicated that a variable herd size mixed/cow-calf-stocker strategy that incorporates productive stockers over the peak of the price cycle and maximizes replacements at the bottom of the price cycle may be profitable when the stockers are viewed as secondary sources of income.

Previous research determined that it is profitable to expand and contract the brood cow herd at different points in the price cycle. Expanding the herd during the upphase of the cycle (Strategy 5E) increased net profits over a similar constant herd size strategy (Strategy 4B). For this model, expanding the herd from 100 cow-equivalents to 115 cow-equivalents during the upphase of the cycle took advantage of replacement and culling strategies as well as stocker retention strategies.

Incorporating stockers into a cow-herd was generally unprofitable unless the stockers were incorporated over the peak of the price cycle. The stockers should be viewed as secondary sources of income to cows and be used to expand the herd size over the peak of the cycle. For a 100-head cow herd, 10-16 stockers should be held over the peak years. Preference should be given to larger, faster-growing stockers.

July was found to be the best month for selling stockers. Low growth rates over fall and winter months eliminated fall, winter, and spring stocker sales. This left summer months to be considered.

June and July yielded comparable net returns and took advantage of higher growth rates for May through July. Early July (July 1) appeared to be the best date for selling stockers as it took advantage of June growth rates and was the mid-point of the June-July highest profit months.

In response to the objectives outlined in Chapter one, results of the research are as follows:

1. Determine if it is profitable to expand and contract the brood cow herd at certain points in the cattle price cycle, and if so, when and how much. The research indicated that expansion of the brood cow herd during the upphase of the cycle and contraction of the brood cow herd during the downphase of the cattle price cycle are profitable practices and can increase herd profits. With year one as the peak of the cattle price cycle, expansion of the herd size by culling and replacement practices during years six through nine allows the ranch to retain replacement heifers when they are relatively "cheap" and to sell cull cows to offset losses incurred by increased heifer retention. The pragmatic herd strategy indicated that expansion of the herd from 100-head in year five to 115-head in years 10 through the peak of the price cycle (year 1) would increase net profits.

2. Determine if it is profitable to change the brood cow/stocker cattle enterprise composition at certain points in the price cycle, and if so, when and how much. The research indicates that reducing the number of replacement heifers over the peak of the cycle, "slowing down" cow culling, and holding stockers over the peak of the price cycle is profitable. Stocker retention allows feeder sales to take advantage of high prices. Reduction of heifer replacement increases

the number of feeder heifers available for sale and reduces investment costs of relatively expensive replacement heifers. With year one as the peak of the cattle price cycle, incorporating stockers over years 10 through 12 and one through three is advantageous. In doing this, the pragmatic strategy expanded the herd to 115-head in years one and 10 through 12 and allowed the herd to drop to 105-head in years two and three.

3. Determine the optimal month for selling stocker cattle during the year and whether this month changes over the cycle or as a part of a long-run strategy. July was determined as the best month to sell stockers. Low growth rates associated with fall, winter, and early spring grazing made November through April sales unprofitable. May sales showed slight improvement. June stocker sales--realizing May productivity--increased returns considerably over May sales. July sales--realizing June productivity--had marginal gains over June sales. As both productivity and monthly prices declined, profitability dropped for August through November stocker sales. Early July was chosen as the pragmatic "best" time to sell stockers. For the pragmatic strategy, the month to sell stockers did not change over the cycle.

Recommendations for Future Research

Future research utilizing the model should be focused in these four areas:

1. Increase stocker productivity,
2. Search for an optimal stocker selling strategy,

3. Develop net present values for cows, replacements, and stockers, and
4. Determine the optimal herd size and composition.

Stocker productivity is critical to the recommendations that come from the model's analysis. Research to adjust stocker growth rates to productive rates to productive, well-managed levels would improve the model's credibility and increase returns generated by stockers. Development of a supplemental feed ration that increases stocker growth rates would lend credibility to the model. Also, considering alternative forage or the use of supplemental feeding for growth verses maintenance should improve stocker returns as well as improving the model.

Data generated for individual stockers indicated net returns increase as stocker wean to sales weight increases. Therefore, scenarios developed to determine the ideal weight and sex of calves to be held as stockers should be beneficial to increasing net returns. As the model has the capacity to sell calves at any time or weight between weaning and terminal fat cattle sales weight, scenarios to determine the optimal date, weight, and grade at which to sell each stocker or group of stockers should increase net profits generated by individual stockers. In situations when growth rates are low and wean to sales weight gain is low, emphasis can be placed on holding calves with higher weaning weights. In faster growing situations where a productive stocker can easily surpass an older stocker, the use of multiple sales points would be beneficial. For example, if a cross-section of the weaned calves are held as stockers, faster growing, more productive stockers will tend to "clump" at the top of the weight range. A sales date of March 15 may be chosen to sell the less productive, light-weight stockers. It can then be assumed that stockers that are not sold on March 15 are heavier, more productive stockers. These stockers can be assumed to be a more uniform group and to have a narrower standard deviation than the stockers held at weaning. To narrow the distribution and make the stockers more uniform in size, the K values can be increased on March 15. Selectivity in sales date and stocker weight groups should serve to increase net income by increasing net returns attributed to individual stockers.

The development of net present values criteria to determine the optimal date, weight, and grade to sell each stocker should be undertaken. The relationship of stockers to cows and replacements at different points in the price cycle could be determined by net present values. Scenarios utilizing net present values should allow for optimization of the model and determination of the optimal herd size, structure, and composition at any point in the price cycle.

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